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Postal Address: FNCV, PO Box 13, Blackburn, Victoria 3130, Australia.
Phone +61 (03) 9877 9860;
email: admin@fncv.org.au
www.fncv.org.au

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Address correspondence to:
The Editors, *The Victorian Naturalist*, PO Box 13, Blackburn, Victoria 3130, Australia.
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**Front cover:** Brush-tailed Phascogale, Black Hill Reserve, Kyneton, Victoria. Photo William Terry. See p.128.

# Simulating the effects of climate change on the distribution of the threatened Brush-tailed Phascogale *Phascogale tapoatafa tapoatafa* in eastern Australia

William Terry[1, 3] and Tingbao Xu[2]

[1]Department of Environmental Science and Engineering, Southern Cross University, Lismore, NSW 2480
[2]Fenner School of Environment and Society, Australian National University, Canberra, ACT 2600
[3]Corresponding author: wterry@outlook.com.au

**Abstract**
Climate change has the potential to have a major impact on flora and fauna across Australia. There is a need to investigate the potential impact of climate change at a subspecies level to inform effective conservation management. To date, there have been no studies that have considered the effects of climate change on the distribution and habitat of the Brush-tailed Phascogale *Phascogale tapoatafa tapoatafa*. In this research, the potential changes to the phascogale climatic envelope were modelled to simulate low emissions (RCP2.6) and high emissions (RCP8.5) scenarios for 2075. Six bioclimatic parameters were selected, based on their likelihood of influencing phascogale occupancy. Modelling was conducted separately on two groupings of phascogale that occur in central Victoria and from northern New South Wales to southern Queensland. Of the selected parameters, the maximum temperature of the hottest month was found to have the greatest influence over phascogale distribution. The high emission scenario for 2075 suggests that climatically suitable phascogale habitat would contract by 79% in Queensland, 67% in Victoria and 17% in New South Wales. Suitable habitat would also increase in some areas with large expansions in New South Wales. Habitat connectivity will be essential for allowing phascogales to move through the landscape to reach areas where climate may be most suitable under warming. These projections do not take into account the increase in bushfires and other natural disasters that could exacerbate the effects of climate change. (*The Victorian Naturalist* **137**(5), 2020, 128–139)

**Keywords:** Dasyurid, modelling, habitat, bioclimatic, mammal

## Introduction

The Brush-tailed Phascogale *Phascogale tapoatafa tapoatafa* (Fig. 1) is a small arboreal (<212g) marsupial carnivore that occurs in the eastern states of Australia including Queensland, New South Wales, Victoria and the Australian Capital Territory (Menkhorst 1996). The species is now extinct in South Australia. It is listed as a threatened taxon in Victoria and New South Wales.

Phascogales were once lumped into two genera: Brush-tailed Phascogale *P. tapoatafa* and the smaller Red-tailed Phascogale *P. calura*. Recent genetic differentiation studies using mitochondrial DNA sequencing, showed that the Brush-tailed Phascogale genus actually comprises four highly divergent lineages (Spencer *et al.* 2001). Recent (2015) taxonomic revisions have identified two subspecies that occur in Western Australia, *P.t. wambenger* from the south-west and *P.t. kimberleyensis* from The Kimberley (Aplin *et al.* 2015). The Northern Territory Brush-tailed Phascogale has been identified as a new species, *P. pirata*. Another likely sub-species of Brush-tailed Phascogale occurs in the Cape York Peninsula in the Top End of Queensland (Aplin *et al.* 2015). The remaining Brush-tailed Phascogale *P. tapoatafa tapoatafa* inhabits southern Queensland, New South Wales, Victoria and the Australian Capital Territory.

The Brush-tailed Phascogale undergoes an annual male die-off in the period of July to August following the breeding season. The need to reproduce annually to maintain a population means that the species is sensitive to changes that could potentially contribute to localised extinction.

While there have been a number of studies that have investigated the life history of phascogales (Mansfield *et al.* 2017; Soderquist 1993a, 1993b; Soderquist and Ealey 1994; Soderquist 1995; Traill and Coates 1993; van der Ree *et al.* 2001), there are still unanswered ecological questions for this subspecies. These answers could provide land managers with a greater understanding of the potential challenges faced by phascogales in the future. Climate change has the potential to have a major

Fig. 1. Brush-tailed Phascogale from Kyneton, Victoria.

impact on flora and fauna across Australia. There is a need to investigate the potential impact of climate change at a subspecies level to inform effective conservation management. To date, there have been no studies that have considered the effects of climate change on the distribution and habitat of phascogales.

Climate models predict that climate warming will result in an increase in the mean temperatures and changes in rainfall around the world (Bernstein *et al.* 2008). Warming of the climate is also likely to impact on a range of fauna species through changes to species climate envelopes (Bernstein *et al.* 2008). Climate envelopes are the combination of climate variables where a species lives. Bioclimatic models have been used widely to predict species' geographical distributions and to forecast range shifts from climate change (Beaumont *et al.* 2005; Fischer *et al.* 2001; Handayani *et al.* 2018; Jackson and Claridge 1999; Lindenmayer *et al.* 1991; Pearce and Lindenmayer 1998).

Bioclimatic models combine species occupancy records with surface temperature and precipitation data to calculate species distributions (Busby 1991). The calculated distribution model can then be combined with Global Climate Models (GCM) to simulate changes to the species' climatic envelope. Drawbacks to bioclimatic models include their failure to take into account biotic interactions in determining geographic ranges (Jeschke and Strayer 2008). They also assume that genetic and phenotypic composition of species is constant and that species are unlimited in their dispersal. This means that they do not take into consideration natural barriers such as rugged terrain or elevations, which could influence species distribution.



Despite these drawbacks, the use of bioclimatic models has often been successful in determining present day species distributions (Garcia *et al.* 2016; Jeschke and Strayer 2008). Bioclimatic models provide useful 'first filters' (Beaumont *et al.* 2005) for measuring the potential impact of climate change on species (Araújo *et al.* 2005), but their limitations should be taken into account when interpreting the results (Pearce and Boyce 2006; Pearson and Dawson 2003).

In this research, the climatic envelope for the Brush-tailed Phascogale was modelled using the algorithm BIOCLIM, available as part

of the online Biodiversity and Climate Change Virtual Laboratory. The Virtual Laboratory brings together a suite of modelling tools and makes them freely available for biodiversity researchers (Hallgren *et al.* 2016).

The aim of this investigation was to determine the potential impact of climate change on the climatic envelope of the Brush-tailed Phascogale in eastern Australia. A greater understanding of the potential distribution of species under future warming scenarios will provide land managers with a basis for long-term conservation planning for this threatened species.

**Materials and methods**

A total of 1517 species occupancy records were obtained in September 2018 from peer-reviewed atlas records that included Victoria (Victorian Biodiversity Atlas), New South Wales (BioNet Atlas) and Queensland (WildNet). Only records of *P. tapoatafa tapoatafa* in eastern Australia were selected as part of the analysis. Isolated records that are contained outside of the main distribution may have been errors and this could influence the modelling to include potentially unsuitable habitat and were therefore removed from the analysis. Duplicates of the same observations were sometimes encountered and were removed.

As there were two main groups of Brush-tailed Phascogale records from different regions, modelling was conducted separately for each as climate and topography parameters were likely to be different (Fig. 2). One group was located in northern New South Wales and southern Queensland. The other group occurred across central Victoria. The phascogales found in the top end of Queensland were excluded from this investigation due to the possibility that they are a different subspecies (Aplin *et al.* 2015).

As there has already been some warming, we refer to the current climate for the species distribution model as the period between 1970 and 2000 (WorldClim Global Climate Data 2017). Occupancy records were cleaned by removing any records after the year 2000 which could have been affected by warming, potentially creating a bias. This left a total of 1088 data points to be used in the analysis (Victoria = 584 and NSW/QLD = 504).

***Climate dataset***

This analysis used climate data from 'South-East Australia Bioclimate Maps: year 2000' which includes a set of 35 bioclimatic parameters from a 20-year average (WorldClim method) for New South Wales, Victoria, the Australian Capital Territory and southern Queensland. A fine resolution of 36 arcsec (~1 km) was selected.

In this analysis, we used the algorithm BIOCLIM (Busby 1991; Booth *et al.* 2014), which is a profile modelling tool that characterises occurrence data with bioclimatic parameters to create a species distribution. BIOCLIM assumes that the current distribution of a species is a good indication of the ecological requirements (Hallgren *et al.* 2016). Shabini *et al.* (2016) found that BIOCLIM performed well, with similar results to other correlative modelling approaches such as MAXENT. Furthermore, Hernandez *et al.* (2006) compared a range of modelling programs and found that BIOCLIM showed its highest predictive success when large sample sizes of occurrence data (>100) were available and thus should be suitable for the large sample size in this current research. Another benefit in using a profile modelling tool was that clusters of occurrence records were unlikely to influence the projection as seen in machine learning programs such as MAXENT.

Model fit was evaluated by using the area under the curve (AUC) from the receiver-operating characteristics (ROC). An AUC score measures the ability of a model to discriminate between locations where a species is present and locations where the species is absent (Elith *et al.* 2006). An AUC score is shown as a number between 0 (no predictive power) and 1 (100% predictive power). AUC values of 0.8–0.9 equal a good fit between the model and the test data. Values that exceed 0.9 consist of models of excellent fit (Elith *et al.* 2006). Despite some criticisms of the AUC method (Lobo *et al.* 2008), this measure has been used successfully to calculate the accuracy of Species Distribution Models (SDM) (Handayani *et al.* 2018; Shabani *et al.* 2016). An SDM is an area where a species is likely to occur and usually consists of a shaded area on a map.

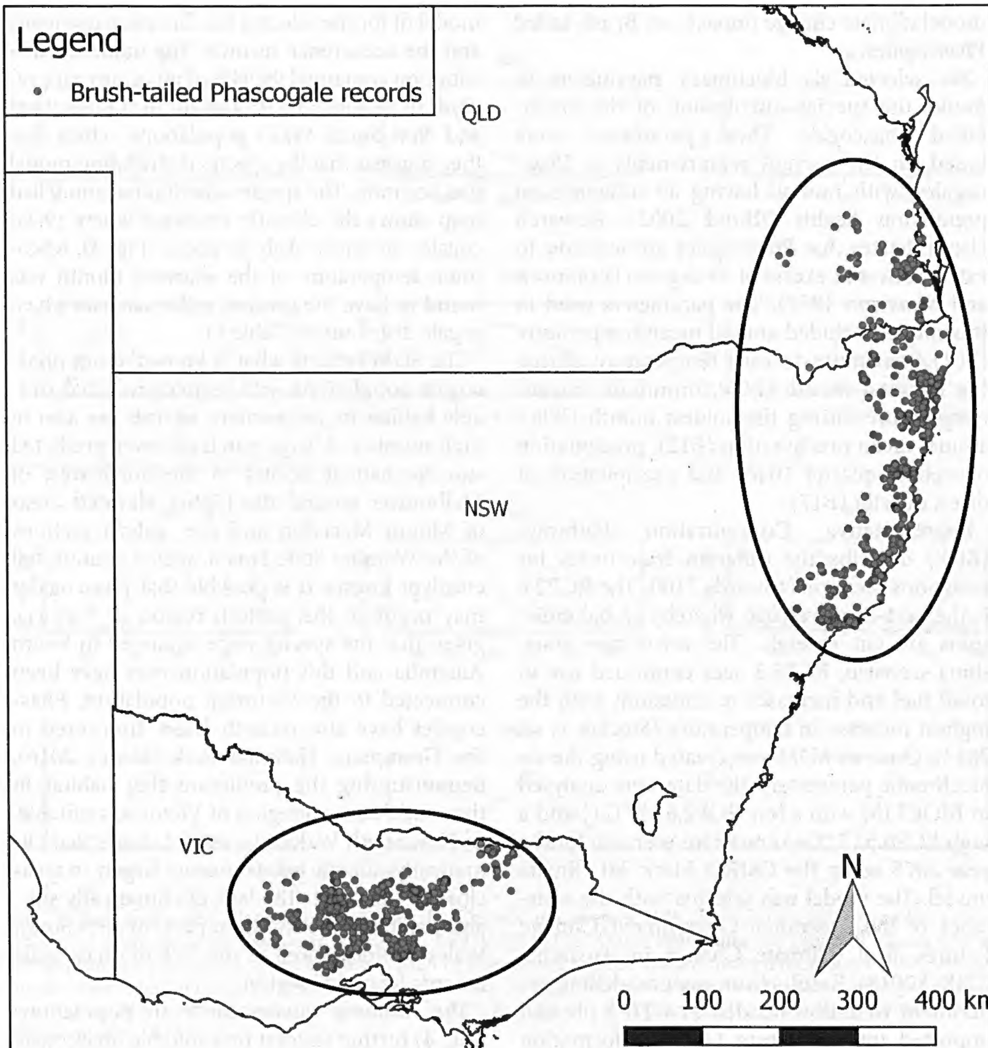



Fig. 2. The occupancy records of Brush-tailed Phascogale used in this experiment. This project used peer-reviewed records for two main groupings in Victoria and southern Queensland through to northern New South Wales.

An additional method used to assess the model was to manually record the number of records which were contained within the current defined climatic envelope.

Porfirio *et al.* (2014) suggest that using all available bioclimatic parameters increases the possibility of over-fitting the species distribution models. This can lead to over-estimation of range reduction and has the potential to forecast extinction of the selected species under climate change. Instead, Porfirio *et al.* (2014) recommended that bioclimatic models should either use a selection of parameters based on statistics to avoid collinearity or a selection of parameters based on biological knowledge and ecological relevance using expert opinions on the selected species. In this research, the latter was used to develop the SDM and to

model climate change impacts on Brush-tailed Phascogales.

We selected six bioclimatic parameters to model the species distribution of the brush-tailed phascogale. These parameters were based on the current requirements of Phascogales, with rainfall having an influence on population health (Rhind 2002). Research also indicates that Phascogales are sensitive to extreme heat in excess of 39 degrees (Robinson and Morrison 1957). The parameters used in this model included annual mean temperature (B01), maximum (mean) temperature during the warmest month (B05), minimum (mean) temperature during the coldest month (B06), annual mean precipitation (B12), precipitation of wettest quarter (B16) and precipitation of driest quarter (B17).

Representative Concentration Pathways (RCP) describe the different trajectories for emissions scenarios towards 2100. The RCP2.6 is the best-case scenario whereby global emissions are cut severely. The worst-case emissions scenario, RCP8.5 sees continued use of fossil fuel and increases in emissions with the highest increase in temperature (Stocker *et al.* 2013). Once an SDM was created using the six bioclimatic parameters, the data were analysed in BIOCLIM with a low RCP2.6 (1 °C+) and a high RCP8.5 (4 °C+) emissions scenario for the year 2075 using the CSIRO Mark 3.0 climate model. The model was selected with the assistance of the Australian Government Climate Futures Tool (Climate Change in Australia, CSIRO 2018). Results from each modelling experiment were downloaded as a TIFF file and imported into Quantum Global Information System software Geographic Information System (QGIS Development Team 2018). Results of the algorithm BIOCLIM provide marginal response curves for each bioclimatic parameter. Statistics on contraction, expansion and unchanged climatic envelope were extracted from the software on offer as part of the package with online Biodiversity and Climate Change Virtual Laboratory (Hallgren *et al.* 2016).

**Results**

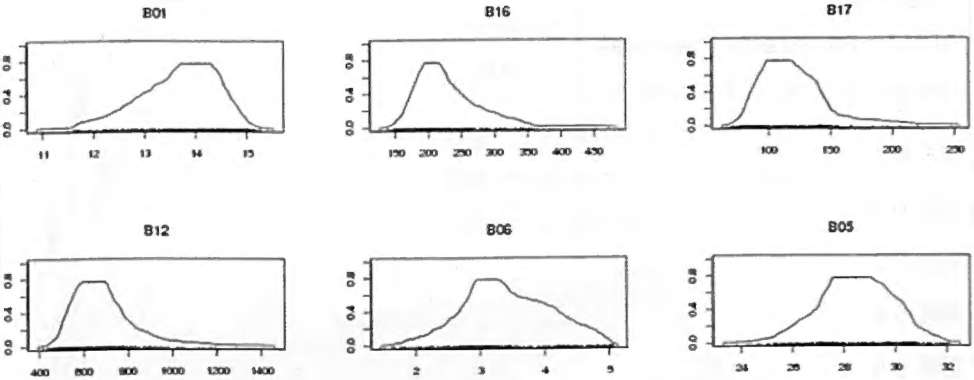
Model AUC values were high for both the Queensland and New South Wales (AUC = 0.97) population model, and the Victorian model (AUC = 0.98), which represented an excellent model fit for the selected bioclimatic parameters and the occurrence records. The modelled distribution contained 99.94% of all occurrence records in Victoria and 95.44% for the Queensland and New South Wales populations, which further suggests that the species distribution model was accurate. The species distribution modelled map shows the climatic envelope where phascogales are most likely to occur (Fig. 3). Maximum temperature of the warmest month was found to have the greatest influence over phascogale distribution (Table 1).

The SDM reflects what is known about phascogale populations with higher predicted suitable habitat in areas where records are also in high number. A large patch of lower predicted suitable habitat occurs to the north-west of Melbourne around the higher elevated areas of Mount Macedon and the eastern sections of the Wombat State Forest, which contain tall eucalypt forests. It is possible that phascogales may occur in the western region of Victoria, given that the species once occurred in South Australia and this population may have been connected to the Victorian population. Phascogales have also recently been discovered in the Grampians National Park (Drury 2016), demonstrating the prediction that habitat in the south-western region of Victoria is suitable. In New South Wales, the model shows that climatically suitable habitat occurs largely in areas close to the coast. The lack of climatically suitable habitat in the southern parts of New South Wales conforms well to the lack of phascogale records from this region.

The response curves for both populations (Fig. 4) further suggest that suitable phascogale habitat is defined by warmer climates. While there were a number of similarities between the different geographical populations, the most suitable phascogale habitat in the northern (Queensland and New South Wales) population had double the annual precipitation (mean 1200 mm) compared to Victoria (600 mm). Victorian phascogales also appeared to have a wider tolerance of annual temperatures when compared to the northern population, which had a sharp increase in habitat use with an annual mean of 19 °C.

The modelling suggests that climate change will have a substantial impact on the available

Victoria




New South Wales and Queensland

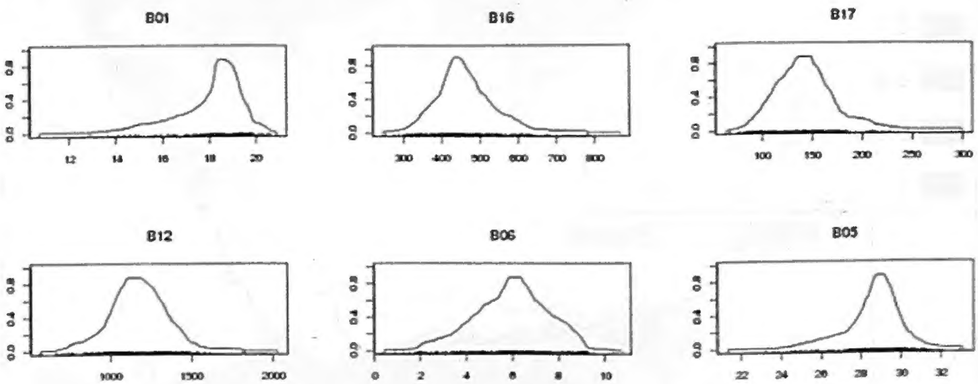



**Fig. 3.** Response curve diagrams for each of the climatic parameters, with the Y-axis representing the probability of occurrence on a scale from 0 (low) to 1 (high). The X-axis represents the range of values of the environmental parameter. The parameters used in this model include annual mean temperature (B01), maximum (mean) temperature during the warmest month (B05), minimum (mean) temperature during the coldest month (B06), annual mean precipitation (B12), precipitation of wettest quarter (B16) and precipitation of driest quarter (B17).

**Table 1.** Importance of climatic parameters for each species distribution model. The modelling was able to identify how important each parameter was for influencing suitable habitat for phascogales. A higher percentage indicates a parameter of higher importance.

| **Climate parameter** | **Description** | **Vic (%)** | **NSW/QLD (%)** |
|---|---|---|---|
| B05 | Max. temperature of hottest month | 29 | 27 |
| B06 | Min. temperature of coldest month | 24 | 23 |
| B12 | Annual precipitation | 20 | 18 |
| B17 | Precipitation of the driest quarter | 13 | 14 |
| B16 | Precipitation of wettest quarter | 9 | 11 |
| B01 | Annual temperature | 5 | 1 |

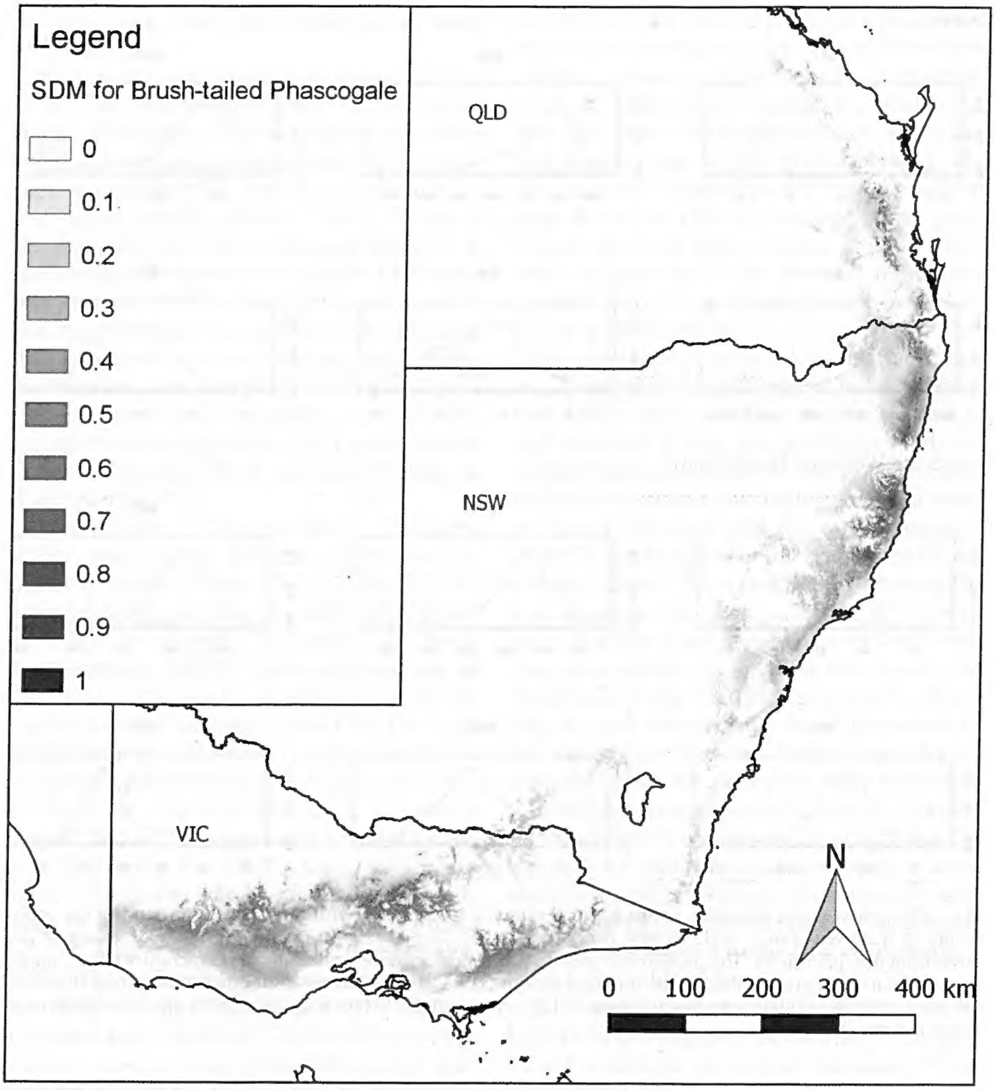



**Fig. 4.** Map of suitable climate for brush-tailed phascogale in eastern Australia with the probability ranging from low (0) to high (1). This map combines data from two species distribution models (SDM) completed.

climatically suitable habitat. A high emission scenario for 2075 suggests that climatically suitable phascogale habitat would contract by 79% in Queensland, 67% in Victoria and 17% in New South Wales (Table 2). The climate change projection maps illustrate the suitable habitat under two emissions scenarios for 2075 (Figs. 5 and 6).

In Victoria, the worst-case scenario suggests that suitable habitat will be lost to the populations of phascogales in the Box-Ironbark forests of Bendigo, while the large populations around Nillumbik and Seymour would also be impacted. It is possible that unaffected areas in the Macedon Ranges and Daylesford regions may become more climatically suitable and an important refuge area for phascogales under future warming. In New South Wales, suitablehabitat will be lost from the coastal areas that stretch from Lismore north to the

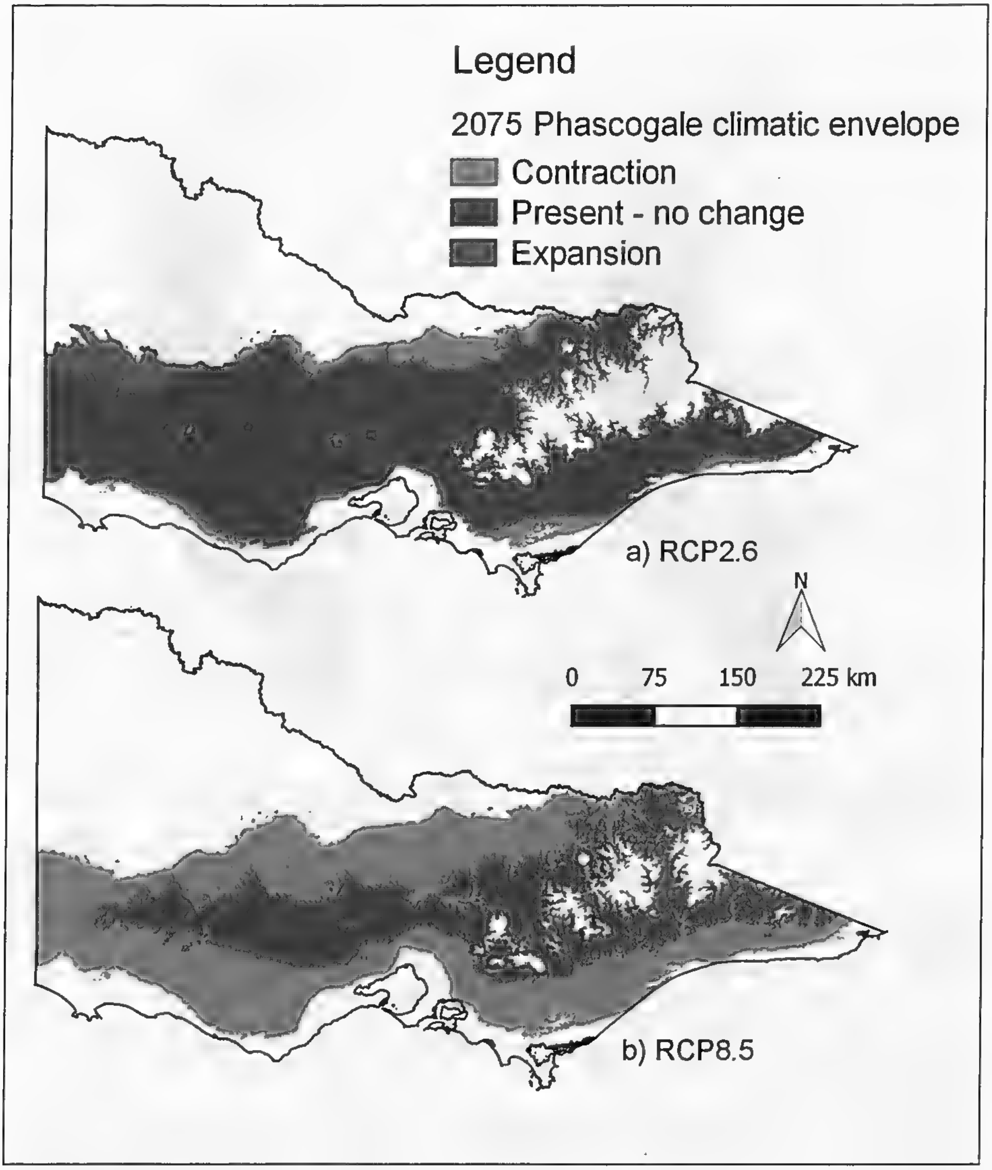



**Fig. 5.** Potential changes in the brush-tailed phascogale climatic envelope in Victoria, with a low (RCP2.6) and high (RCP8.5) emissions scenario.

Coast in Queensland. However, these losses of climatically suitable areas for northern populations will be offset by large increases in habitat opening up inland of Guy Fawkes River National Park. The populations of phascogales that occur near the coast in New South Wales and Queensland will also be impacted.

## Discussion

The results presented here suggest that climate change would have a large impact on suitable phascogale habitat in Victoria and Queensland. In Victoria, the modelling shows that changes to the phascogale climatic envelope would see habitat lost to the populations that occur to

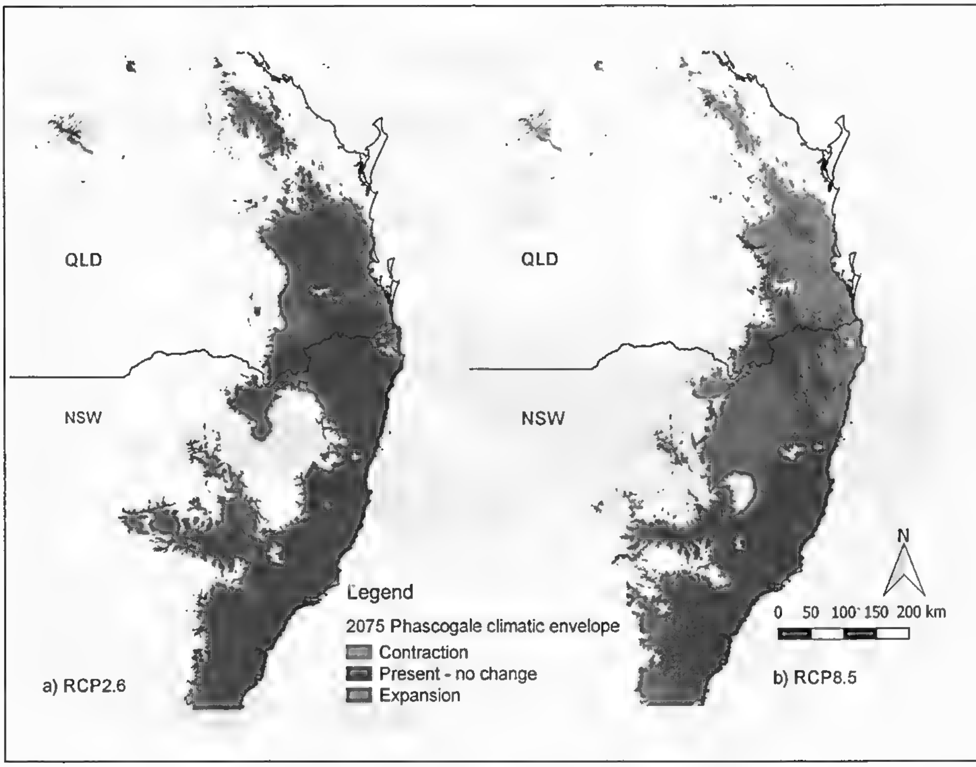



**Fig 6.** Potential changes in the Brush-tailed Phascogale climatic envelope in southern Queensland and northern New South Wales, with a low (RCP2.6) and high (RCP8.5) emissions scenario.

**Table 2.** Overview of climatic envelope changes for a low (RCP2.6) emissions scenario and a high (RCP8.5) emissions scenario for 2075 for each state.

| | VIC | | NSW | | QLD | |
|---|---|---|---|---|---|---|
| | Area km² | % change | Area km² | % change | Area km² | % change |
| **Low emission scenario for 2075** | | | | | | |
| Contraction | 13810.50 | -12.03 | 3878.10 | -4.03 | 7568.93 | -17.63 |
| No change | 100911.12 | 87.97 | 92224.13 | 95.97 | 35343.83 | 82.37 |
| Expansion | 9120.87 | +7.95 | 30260.88 | +31.48 | 13754 | +32.05 |
| **High emission scenario for 2075** | | | | | | |
| Contraction | 77957.86 | -67.95 | 17140.28 | -17.83 | 33928.44 | -79.06 |
| No change | 36763.77 | 32.05 | 78961.95 | 82.17 | 8984.32 | 20.94 |
| Expansion | 11062.00 | +9.64 | 58782.28 | +61.16 | 2712.19 | +5.78 |

the north-east of Melbourne. Losses of habitat would also be experienced in the Box Ironbark forests of Bendigo, which currently support healthy populations of phascogales (Goldingay *et al.* 2018).

In Queensland, the modelling shows that there would be losses of habitat with only small fragments remaining for phascogale occupation. In northern New South Wales, coastal populations of phascogale would be impacted, but there would be large expansions of climatically suitable habitat further inland.

It should be noted that modelling species distributions has several limitations. The projected area shows locations where the climate is suitable for the species, but this is not a measure of the actual distribution of phascogale populations. Some habitat requirements by species are independent of climatic suitability (Green *et al.* 2008), which could include factors such as opportunity for dispersal, human disturbance, competition, specific food resources, landscape elevation and ruggedness. To improve our understanding of how this species will respond to climate change, there is a need to build on the findings presented here with more research into how other variables influence habitat selection by phascogales.

Despite the limitations of species distribution modelling, the purpose of this study was to gauge the potential impact of climate change on Brush-tailed Phascogales in eastern Australia. This study shows that a high emission scenario has the potential to modify large sections of habitat for Brush-tailed Phascogales. The species is currently not listed as a threatened taxon in Queensland. However, given the results presented in this paper, the species would be at greater risk of extinction in this state.

It is possible that climate change will have a greater impact on phascogale populations than what has been predicted here. Climate change will see an increasing number of extreme fire danger days, by up to 70% by 2050 (Hennessy *et al.* 2005). This could have consequences for phascogales if it equates to more bushfires. Research is yet to demonstrate how phascogales interact with post-fire landscapes but observations by researchers suggest that it is likely to be negative (Andrew Bennett, LaTrobe University, pers. comm., 2015). The feeding behaviour of phascogales involves stripping bark from eucalypts to search for invertebrates (Traill and Coates 1993). Trees that have been burnt have thick charcoal bark for decades after a fire, which could reduce the availability of feed trees, forcing phascogales to browse over greater distances (Terry and Johnson 2018). Climate change will also see an increase in natural disasters (Banholzer *et al.* 2014; Van Aalst 2006). A study of the smaller Western Australian phascogale *P.t. wambenger* (Rhind 2002; Rhind and Bradley 2002) found that this species was particularly sensitive to drought periods, which had a drastic impact on the condition of females and the dispersal ability of males. It is likely that the closely related subspecies investigated in our paper will also suffer similar impacts under natural disasters such as droughts.

An increase in heat waves could also have devastating consequences for phascogales. A study of the heat tolerance of Australian mammals found that a phascogale became intolerant to heat once air temperature rose above body temperature. Phascogales exposed to hot temperatures (39 °C+) made no attempt to increase body evaporation and instead relied on radiation and conduction for heat dispersal (Robinson and Morrison 1957). The species distribution model used in this research also confirmed that the maximum temperature of the hottest month had the greatest influence on the selected parameters for phascogale habitat selection. While phascogales preferred warmer climates, occupancy declined where mean temperatures of the hottest month increased above 29 degrees. It should be noted that the relationship between temperature and phascogales seen in the species distribution model might not be causative. For example, Mallee environments that have very hot temperatures may be unsuitable because of inappropriate vegetation or food sources for phascogales.

Large thick-walled hollows may be able to offset extreme summer heat encountered by phascogales. However, in some areas, forests are too young to provide large hollow-bearing trees and residing in shallower cavities would likely offer less protection from air temperatures. High-quality nesting refuges that provide a greater level of protection from temperature extremes will be essential in a warming climate.

Nest boxes are often used as additional refuges in disturbed landscapes (Dashper and Myers 2003; Myers 1997). The use of nest boxes may be inappropriate for future conservation programs as they are unlikely to offer an optimal thermal protection during extreme weather events (Goldingay 2015; Griffiths *et al.* 2018; Griffiths *et al.* 2017; Larson *et al.* 2018; Rueegger 2017). Retention of existing old growth trees that already possess large thermal protective hollows will be essential for long-term conservation of phascogales as these provide a greater level of protection from external climatic temperatures (Rowland *et al.* 2017). Chainsaw hollows (Rueegger 2017) and other alternatives to traditional plywood nest boxes will also need to be developed for areas where forests are still too young to provide adequately sized natural hollows.

The maps as presented in this paper also show large areas that may provide suitable habitat for phascogales during a warming climate. The effects of climate change on phascogales could potentially be reduced by improving connectivity throughout the species' range to allow for migration to areas that are more climatically suitable (Nuñez *et al.* 2013).

Long-term monitoring programs for phascogales (Goldingay *et al.* 2018; Holland *et al.* 2012) will be essential for successful management of this species and will allow land managers to be responsive to sudden changes in populations. The information provided in this paper provides a first step in understanding the impact climate change will have on phascogales. However, further research is needed to identify how phascogale habitat will change and if the species can adapt to changes.

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## References

Aplin KP, Rhind SG, Have JT and Chesser RT (2015) Taxonomic revision of *Phascogale tapoatafa* (Meyer, 1793) (Dasyuridae; Marsupialia), including descriptions of two new subspecies and confirmation of *P. pirata* Thomas, 1904 as a 'Top End' endemic. *Zootaxa*, **4055**, 1–73.

Araújo MB, Pearson RG, Thuiller W and Erhard M (2005) Validation of species–climate impact models under climate change. *Global Change Biology* **11**, 1504–1513.

Banholzer S, Kossin J, Donner S (2014) The impact of climate change on natural disasters. In *Reducing disaster: early warning systems for climate change*, pp. 21–49. Eds A Singh and Z Zommers. (Springer: Dordrecht).

Beaumont LJ, Hughes L and Poulsen M (2005) Predicting species distributions: use of climatic parameters in BIOCLIM and its impact on predictions of species' current and future distributions. *Ecological Modelling* **186**, 251–270.

Bernstein L, Bosch P, Canziani O, Chen Z, Christ R and Riahi K (2008) *IPCC, 2007: climate change 2007: Synthesis report.* (IPCC: Geneva).

Booth TH, Nix HA, Busby JR and Hutchinson MF (2014) BIOCLIM: The first species distribution modelling package, its early applications and relevance to most current maxent studies. *Diversity and Distributions* **20**, 1–9.

Busby JR (1991) BIOCLIM: a bioclimate analysis and prediction system. *Plant protection quarterly* **6**, 8–9.

CSIRO (2018) Climate Change In Australia: Australian Government Climate Futures Tool. Avalable at <www.climatechangeinaustralia.gov.au/en/climate-projections/climate-futures-tool/introduction-climate-futures/> (Accessed 21 July 2018).

Dashper S and Myers S (2003) The use of artificial nest boxes by Brush-tailed Phascogales *Phascogale tapoatafa* in Rushworth Forest. *The Victorian Naturalist* **120**, 40–47.

Drury R (2016) Surveying for arboreal mammals in the Grampians National Park and adjacent reserves. *The Victorian Naturalist* **133**, 64–71.

Elith J, Graham CH, Anderson RP, Dudík M, Ferrier S, Guisan A, Hijmans RJ, Huettmann F, Leathwick JR and Lehmann A (2006) Novel methods improve prediction of species distributions from occurrence data. *Ecography* **29**, 129–151.

Fischer J, Lindenmayer DB, Nix HA, Stein JL and Stein JA (2001) Climate and animal distribution: A climatic analysis of the Australian marsupial *Trichosurus caninus*. *Journal of Biogeography* **28**, 293–304.

Garcia RA, Cabeza M, Altwegg R and Araújo MB (2016) Do projections from bioclimatic envelope models and climate change metrics match? *Global Ecology and Biogeography* **25**, 65–74.

Goldingay R (2015) Temperature variation in nest boxes in eastern Australia. *Australian Mammalogy* **37**, 225–233.

Goldingay R, Thomas KJ and Shanty D (2018) Outcomes of decades long installation of nest boxes for arboreal mammals in southern Australia. *Ecological Management & Restoration* **19**, 204–211.

Green K, Stein JA and Driessen MM (2008) The projected distributions of *Mastacomys fuscus* and *Rattus lutreolus* in south-eastern Australia under a scenario of climate change: Potential for increased competition? *Wildlife Research* **35**, 113–119.

Griffiths SR, Lentini PE, Semmens K, Watson SJ, Lumsden LF and Robert KA (2018) Chainsaw-carved cavities better mimic the thermal properties of natural tree hollows than nest boxes and log hollows. *Forests* **9**, 235.

Griffiths SR, Rowland JA, Briscoe NJ, Lentini PE, Handasyde KA, Lumsden LF and Robert KA (2017) Surface reflectance drives nest box temperature profiles and thermal suitability for target wildlife. *PLOS ONE*, **12**(5) <e0176951. doi.org/10.1371/journal.pone.0176951>

Hallgren W, Beaumont L, Bowness A, Chambers L, Graham E, Holewa H, Laffan S, Mackey B, Nix H, Price J and Vanderwal J (2016) The biodiversity and climate change virtual laboratory: Where ecology meets big data. *Environmental Modelling & Software* **76**, 182–186.

Handayani F, Goldingay RL, McHugh D and Leslie N (2018) Extensive range contraction predicted under climate warming for a gliding mammal in north-eastern Australia. *Australian Mammalogy* **41**, 99–111.

Hennessy K, Lucas C, Nicholls N, Bathols J, Suppiah R. and Ricketts J (2005) Climate change impacts on fire-weather in south-east Australia. (Bureau of Meteorology/CSIRO: Victoria).

Hernandez PA, Graham CH, Master LL and Albert DL (2006) The effect of sample size and species characteristics on performance of different species distribution modeling methods. *Ecography* **29**, 773–785.

Holland GJ, Alexander JSA, Johnson P, Arnold AH, Halley M and Bennett AF (2012) Conservation cornerstones: Capitalising on the endeavours of long-term monitoring projects. *Biological Conservation* **145**, 95–101.

Jackson SM and Claridge A (1999) Climatic modelling of the distribution of the Mahogany Glider (*Petaurus gracilis*), and the Squirrel Glider (*P. norfolcensis*). *Australian Journal of Zoology* **47**, 47–57.

Jeschke JM and Strayer DL (2008) Usefulness of bioclimatic models for studying climate change and invasive species. *Annals of the New York Academy of Sciences* **1134**, 1–24.

Larson ER, Eastwood JR, Buchanan KL, Bennett ATD and Berg ML (2018) Nest box design for a changing climate: the value of improved insulation. *Ecological Management & Restoration* **19** 39–48.

Lindenmayer DB, Nix HA, McMahon JP, Hutchinson MF and Tanton MT (1991) The conservation of Leadbeater's possum, *Gymnobelideus leadbeateri* (McCoy): A case study of the use of bioclimatic modelling. *Journal of Biogeography* **18**, 371–383.

Lobo JM, Jiménez-Valverde A and Real R (2008) AUC: A misleading measure of the performance of predictive distribution models. *Global Ecology and Biogeography* **17**, 145–151.

Mansfield C, Arnold AH, Bell TL and York A (2017) Habitat characteristics of a threatened arboreal marsupial and its resource use in a degraded landscape: The Brush-tailed Phascogale (*Phascogale tapoatafa tapoatafa*) in central Victoria, Australia. *Wildlife Research* **44**, 153–164.

Menkhorst P (1996) *Mammals of Victoria: distribution, ecology and conservation*, (Oxford University Press/ Department of Conservation and Natural Resources: Melbourne).

Myers S (1997) A note on Sugar Glider *Petaurus breviceps* use of Brush-tailed Phascogale *Phascogale tapoatafa* nests in nest boxes at Rushworth State Forest. *The Victorian Naturalist* **114**, 240–241.

Nuñez TA, Lawler JJ, Mcrae BH, Pierce DJ, Krosby MB, Kavanagh DM, Singleton PH and Tewksbury JJ (2013) Connectivity planning to address climate change. *Conservation Biology* **27**, 407–416.

Pearce J and Lindenmayer D (1998) Bioclimatic analysis to enhance reintroduction biology of the endangered Helmeted Honeyeater (*Lichenostomus melanops cassidix*) in south eastern Australia. *Restoration Ecology* **6**, 238–243, <doi:10.1046/j.1526-100X.1998.00636.x>

Pearce J and Boyce M (2006) Modelling distribution and abundance with presence-only data. *Journal of Applied Ecology* **43**, 405–412, <doi:10.1111/j.1365-2664.2005.01112.x>

Pearson RG and Dawson TP (2003) Predicting the impacts of climate change on the distribution of species: Are bioclimate envelope models useful? *Global Ecology and Biogeography* **12**, 361–371, <doi:10.1046/j.1466-822X.2003.00042.x>

Porfirio LL, Harris RMB, Lefroy EC, Hugh S, Gould SF, Lee G, Bindoff NL and Mackey B (2014) Improving the use of species distribution models in conservation planning and management under climate change. *PLOS ONE* **9**, <e113749, 10.1371/journal.pone.0113749>

QGIS Development Team (2018) *QGIS Geographic Information System*. (Open Source Geospatial Foundation Project).

Rhind S (2002) Reproductive demographics among Brush-tailed Phascogales (*Phascogale tapoatafa*) in south-western Australia. *Wildlife Research* **29**, 247–257.

Rhind S and Bradley J (2002) The effect of drought on body size, growth and abundance of wild Brush-tailed Phascogales (*Phascogale tapoatafa*) in south-western Australia. *Wildlife Research*, **29**, 235–245.

Robinson K and Morrison P (1957) The reaction to hot atmospheres of various species of Australian marsupial and placental animals. *Journal of Cellular and Comparative Physiology* **49**, 455–478.

Rowland JA, Briscoe NJ and Handasyde KA (2017) Comparing the thermal suitability of nest-boxes and tree-hollows for the conservation-management of arboreal marsupials. *Biological Conservation* **209**, 341–348, <https://doi.org/10.1016/j.biocon.2017.02.006>

Rueegger N (2017) Artificial tree hollow creation for cavity-using wildlife — trialling an alternative method to that of nest boxes. *Forest Ecology and Management* **405**, 404–412, <https://doi.org/10.1016/j.foreco.2017.09.062>

Shabani F, Kumar L and Ahmadi M (2016) A comparison of absolute performance of different correlative and mechanistic species distribution models in an independent area. *Ecology and Evolution* **6**, 5973–5986, <10.1002/ece3.2332>

Soderquist T (1993a) Maternal strategies of *Phascogale-tapoatafa* (Marsupialia, Dasyuridae) .1. Breeding seasonality and maternal investment. *Australian Journal of Zoology* **41**, 549–566, <https://doi.org/10.1071/ZO9930549>

Soderquist T (1993b) Maternal strategies of *Phascogale-tapoatafa* (Marsupialia, Dasyuridae). 2. Juvenile thermoregulation and maternal attendance. *Australian Journal of Zoology* **41**, 567–576, <https://doi.org/10.1071/ZO9930567>

Soderquist TR (1995) Spatial organization of the arboreal carnivorous marsupial *Phascogale tapoatafa*. *Journal of Zoology* **237**, 385–398, <10.1111/j.1469-7998.1995.tb02769.x>

Soderquist T and Ealey L (1994) Social interactions and mating strategies of a solitary carnivorous marsupial, *Phascogale tapoatafa*, in the wild. *Wildlife Research* **21**, 527–541, <https://doi.org/10.1071/WR9940527>

Spencer PBS, Rhind SG and Eldridge MDB (2001) Phylogeographic structure within phascogale (Marsupialia : Dasyuridae) based on partial cytochrome sequence. *Australian Journal of Zoology* **49**, 369–377 <https://doi.org/10.1071/ZO00080>

Stocker, T, Dahe, Q and Plattner, GKE (2013) *The Physical Science Basis*. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. (Cambridge University Press: Cambridge).

Terry W and Johnson P (2018) A survey for non-volant mammals in Cobaw State Forest in central Victoria. *The Victorian Naturalist* **135**, 10–15.

Traill BJ and Coates TD (1993) Field observations on the Brush-tailed Phascogale *Phascogale tapoatafa* (Marsupialia: Dasyuridae). *Australian Mammalogy* **16**, 61–65.

Van Aalst MK (2006) The impacts of climate change on the risk of natural disasters. *Disasters* **30**, 5–18, <doi:10.1111/j.1467-9523.2006.00303.x.>

van der Ree R, Soderquist TR and Bennett AF (2001) Home-range use by the Brush-tailed Phascogale (*Phascogale tapoatafa*) (Marsupialia) in high-quality, spatially limited habitat. *Wildlife Research* **28**, 517–525.

WorldClim (2017) WorldClim Global climate data,<www.worldclim.org>.

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# A close-up look at biodiversity offsetting in Victoria

Anna O'Brien[1,2] and Ascelin Gordon[1]

[1]School of Global, Urban and Social Studies, RMIT University, Melbourne, Victoria;
[2]Biodiversity Offsets Victoria, <www.offsetsvictoria.com.au>

**Abstract**
Biodiversity offsetting seeks to balance losses in biodiversity from development impacts with offset actions that generate gains in biodiversity. Under Victorian biodiversity offsetting policy, offsets are required to compensate for the permitted removal, destruction or lopping of native vegetation, and aim to achieve *No Net Loss* in biodiversity. In this paper, we outline the policy and examine a recently permitted impact-offset exchange. We review how No Net Loss is proposed to be achieved under this exchange and evaluate the gains that were predicted to be generated over the offset management period. Victorian data on the rates of change in native vegetation indicate that the gains from the offset are likely to be overestimated, meaning the offset does not compensate for the impact, resulting in a *Net Loss* in biodiversity. We discuss how the lack of a suitable assessment framework for offsets in Victoria is a significant limitation for a rigorous evaluation of the gains from offsetting and argue a review of Victorian offsetting policy is needed to address these failings. (*The Victorian Naturalist* 137(5), 2020,140–152)

**Keywords:** biodiversity offsets, No Net Loss, Victorian offsetting policy, native vegetation, biodiversity metrics

## Introduction

Biodiversity offsetting is a regulatory instrument that seeks to balance biodiversity loss from development through the generation of measurable 'gains' in biodiversity over a specified timeframe (e.g. a 10 or 20-year offset management period; IUCN 2014). Offset policy objectives include No Net Loss (gains equal losses) or Net Gain (gains greater than losses) in biodiversity. In theory, under an effective offsetting scheme, development should have, at least, a neutral impact on biodiversity after the offset management period (IUCN 2014; Gibbons *et al.* 2015).

Offsetting schemes are in place in over 80 different countries worldwide, including separate schemes in all Australian states and Territories (Maron *et al.* 2015a, 2018). The efficacy of offsetting to meet its policy objectives is, however, continually called into questioned (Bull *et al.* 2013; Quétier *et al.* 2014; OECD 2016). In particular, the predicted gains from offsetting may not be plausible or transparent, and, in some cases, are overestimated (Maron *et al.* 2015b; Dorrough *et al.* 2019). If offsets do not deliver their expected gains in biodiversity, a No Net Loss outcome is not achieved, and losses from permitted impacts will lead to net loss in biodiversity.

In Victoria, biodiversity offsets are generated to compensate for impacts under both State and Federal legislative requirements. In this paper, we outline the biodiversity offsetting policy under the Victorian *Planning and Environment Act 1987*, which aims to achieve 'no net loss in biodiversity as a result of the removal, destruction or lopping of native vegetation' (Department of Environment, Land, Water and Planning (DELWP) 2020a, Clauses 12.01-2S, 52.16 and 52.17). We present an impact-offset exchange recently permitted under this policy to illustrate how policy attempts to achieve equivalence between the impact and offset through the specified units of loss and gain. We then examine the predicted gains from the offset and discuss whether a No Net Loss outcome is likely to be achieved.

## Target impacts to target biota

Biodiversity offsetting policies do not target all components of biodiversity, rather biodiversity is defined by the metrics used and the scope of the policy (Maron *et al.* 2018). In Victoria, biodiversity offsets are required to compensate for permitted impacts to native vegetation under the *Planning and Environment Act 1987*, including potential habitat for species listed under Victoria's advisory lists of rare or threatened plants and animals (Department of Sustainability and Environment (DSE) 2013; Department of Environment and Primary

Industry (DEPI 2014). The Victorian *Guidelines for the removal, destruction or lopping of native vegetation* (2017 Guidelines) (DELWP 2017a) defines native vegetation as 'plants that are indigenous to Victoria, including trees, shrubs, herbs and grasses' (DELWP 2017a, p. 6).

Permitted impacts to native vegetation are typically associated with residential, industry and infrastructure developments. Offsets are not required for impacts to native vegetation that are beyond the scope of the policy, such as illegal clearance, climate change, pollution and waste, or pest plant and animal invasion. There are also a range of exempt activities that may not require a planning permit or offset for impacts to native vegetation, such as impacts on land titles less than 0.4 ha, for personal use on land titles greater than 10 ha, fencing maintenance, domestic stock grazing and within 10 m of an existing building (DELWP 2017b; DELWP 2020a).

**Mitigation hierarchy**

The mitigation hierarchy guides decisions by regulatory authorities on whether to permit an impact to biodiversity. Under Clauses 52.16, 52.17 and 12.01-2S of the Victorian Planning Schemes, the following three-step mitigation hierarchy must be applied to all applications to remove native vegetation:

1. Avoid the removal, destruction or lopping of native vegetation;
2. Minimise impacts from the removal, destruction or lopping of native vegetation that cannot be avoided; and
3. Provide an offset to compensate for the biodiversity impact if a permit is granted to remove, destroy or lop native vegetation (DELWP 2020a).

The mitigation hierarchy should ensure that permitted biodiversity losses are restricted to what is absolutely necessary under each development proposal, with offsets treated as a last resort. However, the 2017 Guidelines outline only non-binding considerations for authorities to assess efforts to avoid and minimise impacts to native vegetation and threatened species habitat. There is also an overlap in the definitions of Steps 1 and 2 in the 2017 Guidelines, as avoidance and minimisation both involve development siting and design away from native vegetation (DELWP 2017a). In the absence of clear and enforceable standards, there is a risk that offsetting becomes the first and only step undertaken in the mitigation hierarchy (Bull *et al.* 2016; Maron *et al.* 2018).

**No Net Loss**

The 2017 Guidelines outline the Victorian Government's approach to achieving No Net Loss in biodiversity, through the planning, assessment and offsetting requirements of native vegetation proposed to be impacted from development (DELWP 2017a). To achieve No Net Loss in biodiversity from development, an equivalence must be demonstrated between the permitted loss in biodiversity from the impact, and the expected gain in biodiversity from the offset (Maseyk *et al.* 2016; Maron *et al.* 2018). The Convention on Biological Diversity (CBD) requires that gains in biodiversity from offsetting would not have otherwise been achieved without the offset (CBD 2011; Maron 2015). Gains from offsetting must therefore be *additional* to any existing land management requirements, and conservation commitments and targets, in order to compensate for the permitted loss and achieve a No Net Loss objective (Maron *et al.* 2015b).

**Measuring Loss and Gain**

To evaluate equivalence and demonstrate No Net Loss, the same metrics of biodiversity must be used to quantify both the losses and gains (Peterson *et al.* 2018). Under Victorian offsetting policy, native vegetation is assessed as a patch or scattered tree, where a *patch of native vegetation* is either:

- an area of vegetation where at least 25% of the total perennial understorey plant cover is native; or
- any area with three or more native canopy trees where the drip line of each tree touches the drip line of at least one other tree, forming a continuous canopy; or
- any mapped wetland included in the Current Wetlands Map (DELWP 2017a, 2020b).

A *scattered tree* is a native canopy tree that does not form part of a patch. It may be large or small in accordance with the relevant Ecological Vegetation Class[1] (EVC) benchmark[2] size for a large tree[3], and corresponds to an area

calculated by a circle with either a 15 m radius (0.071 ha—large tree) or 10 m radius (0.031 ha—small tree). The total extent of native vegetation proposed to be removed includes the extent (in hectares) of any patches of native vegetation and scattered trees, and the number of large trees (see Box 1, item 1).

Losses and gains in native vegetation are both measured in General or Species Habitat Units (HUs). However, they incorporate different values. General and Species HUs of loss are measured using a vegetation quality (habitat hectare) assessment[4] methodology (DSE 2004), with the *general* or *species landscape factors*, and the relevant multipliers (see Box 1, items 6 and 7). A habitat hectare is a measure of native vegetation quality and quantity, relative to the relevant EVC benchmark (Parkes *et al.* 2003; DSE 2004; DELWP 2020c). Benchmarks have been developed for each EVC known to occur in each of the 28 Victorian bioregions[5].

The *general landscape factor* is the adjusted *Strategic Biodiversity Value* (SBV) score at the impact site (Fig. 1; Box 1, item 3). The SBV is a modelled score between 0 and 1, which varies across Victoria and reflects a site's ranked contribution to the conservation of Victoria's biodiversity. The SBV map was developed using conservation planning software that incorporates data from species habitat distribution models, and models of vegetation types and condition (Fig. 1; DELWP 2017c). The *species landscape factor* is the adjusted *Habitat Importance Score* (HIS) for a rare or threatened flora and fauna species listed under Victoria's Advisory Lists of rare or threatened plants and animals (DSE 2013; DEPI 2014; Box 1, item 4). The HIS is derived from habitat distribution models for each rare or threatened species (DELWP 2017c). The *species landscape factor* is applied when native vegetation loss will have a significant impact on habitat for a rare or threatened species (DELWP 2017a). Fig. 2 shows an example of the HIS data for the rare Veined Spear-grass *Austrostipa rudis* subsp. *australis* in East Gippsland (DELWP 2020b). Impacts to native vegetation in these areas may require a species offset (measured in Species HUs) for Veined Spear-grass, and offsets in these areas are likely to generate species offsets for Veined Spear-grass.

General and Species HUs of gain are measured using the gain score made up of points awarded under the four types of gain from offsetting: prior management gain, security gain, maintenance gain and improvement gain (Table 1; Box

**Box 1. Metrics for Loss and Gain under Victorian Offsetting Policy (DELWP 2017a)**

| | |
|---|---|
| 1. Native vegetation extent | Extent of patches (ha) + extent of scattered trees (ha) + no. of large trees |
| 2. Habitat score | Vegetation Quality Assessment Score (see Appendix 1) out of 100 |
| 3. General landscape factor | Strategic biodiversity value score/ 2 + 0.5 |
| 4. Species landscape factor | Habitat importance score/ 2 + 0.5 |
| | **Measuring Loss** |
| 5. Habitat hectares of loss | = Habitat Score/100 × Area (Hectares) to be lost |
| 6. General habitat units of loss | = Habitat hectares of loss × general landscape factor × 1.5 + no. Large Trees |
| 7. Species habitat units of loss | = Habitat hectares of loss × species landscape factor × 2 + no. Large Trees |
| | **Measuring Gain** |
| 8. Gain score | Prior Management Gain + Security Gain + Maintenance Gain + Improvement Gain (see Table 1 below) |
| 9. Habitat hectares of gain | = Gain Score/100 × Area (Hectares) to be protected for offset |
| 10. General habitat units of gain | = Habitat hectares of gain × general landscape factor including no. Large Trees |
| 11. Species habitat units of gain | = Habitat hectares of gain × species landscape factor including no. Large Trees |


Fig. 1. Victorian Strategic Biodiversity Value Scores (DELWP 2020b)

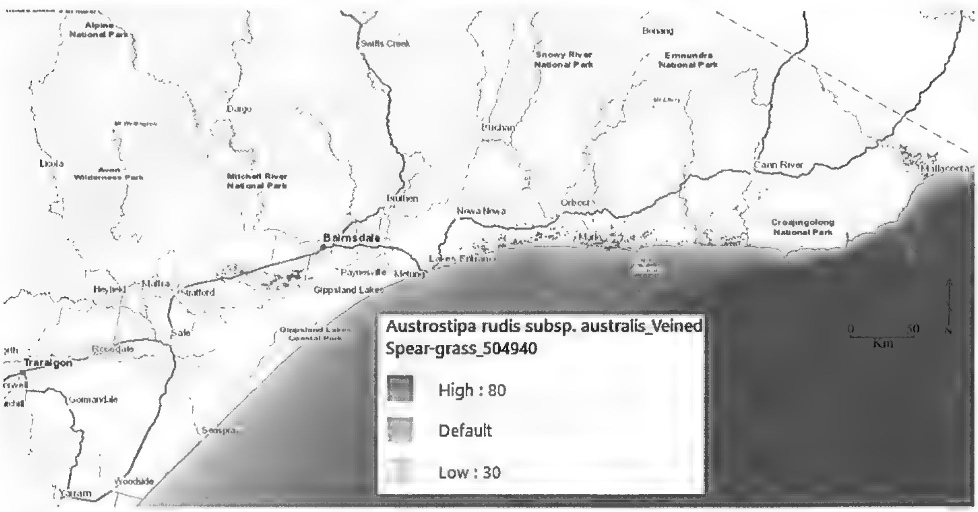



Fig. 2. Habitat Importance Score for Veined Spear-grass in the East Gippsland Shire Council (DELWP 2020b)

1, Row 8). Table 1 outlines each type of gain as described in Victoria's *Native vegetation gain scoring manual — Version 2* (gain scoring manual) (DELWP 2017d), and the potential gain points available under each type according to the offset land tenure, in-perpetuity protection, offset type, vegetation habitat (condition) score at the beginning of the 10-year offset management period, and proposed management activities to be implemented. While losses from development may be immediate, gains from offsetting are generated over a 10-year offset management period, which requires making multiple assumptions about the projected native vegetation condition in 10 years with and without the offset.

As native vegetation is shown to be in continual decline in condition and extent in Victoria (Commissioner for Environmental Sustainability (CES) 2018), gains from offsetting may be generated from measures that maintain the existing native vegetation and avert further

**Table 1.** Types of gain available on freehold and crown land (DELWP 2017d)

| Type of gain | Description | Potential gain points available Freehold | Crown land |
|---|---|---|---|
| **Prior management Gain** | Acknowledging management undertaken by landowners on a freehold site prior to the offset. | 10% of current habitat score | NA |
| **Security gain** | Increasing the administrative protection of native vegetation on freehold or crown land e.g. via a suitable on-title security agreement, or reclassifying freehold, or Crown land, to a more secure Crown land reserve. | 10–20% of current habitat score | 0–10% of current habitat score |
| **Maintenance gain** | Maintaining the current vegetation condition over the offset management period (i.e. averted loss). | Proportionate points of gain for each relevant habitat attribute and foregoing land use entitlements (e.g. livestock grazing, firewood collection). | |
| **Improvement gain** | Improving vegetation condition from management commitments beyond existing obligations under legislation. | Proportionate points of gain for each relevant habitat attribute and proposed actions to improve quality over 10-year management period (e.g. weed control). | |

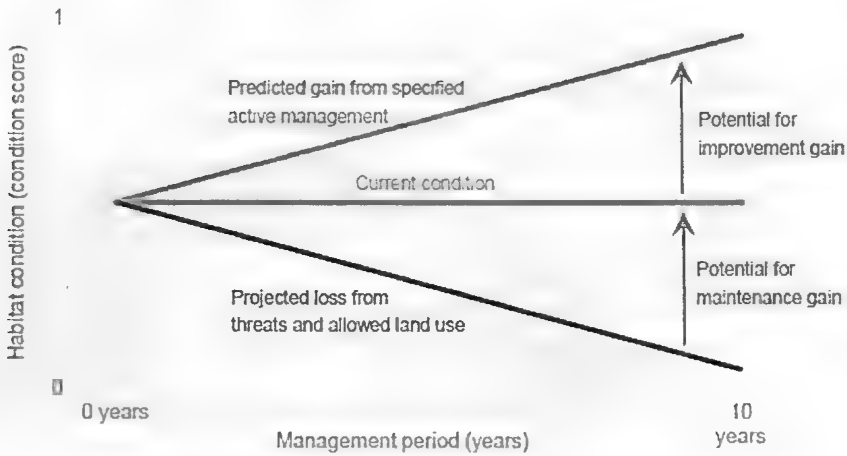



**Fig. 3.** Maintenance and improvement gains (reproduced from DELWP 2017d)

loss, as well as improving the existing biodiversity, over the 10-year offset management period. Fig. 3 illustrates the total gain available from both improvement and maintenance gains in native vegetation relevant to its habitat (condition) score at the beginning of the offset management period, and to its declining baseline value without the offset.

The maintenance gain is generated from averting this projected decline in native vegetation condition over the 10-year offset management period by foregoing existing land use entitlements that may degrade or clear native vegetation, such as agriculture and firewood collection, and controlling potential threats to the native vegetation, such as weed and pest invasions. Improvement gain is generated from undertaking management actions to increase the current native vegetation condition over the 10-year management period. These

management actions must be above and beyond the existing land management obligations, such as native vegetation protection requirements under existing overlays or controlling declared noxious weeds under the *Catchment and Land Protection Act 1994* (CaLP Act). They could include controlling other weeds, pest animals and significant threats to the offset, such as livestock grazing or spray drift from adjacent land, revegetation or supplementary planting, the introduction of logs, and biomass control in grassland ecosystems (DELWP 2017d).

The gain points awarded for maintenance and improvement gains are proportionate to the habitat (condition) score at the beginning of the offset management period, and therefore represent the assumed projected decline in the native vegetation condition without the offset (maintenance) and the assumed projected increase in the native vegetation condition with the offset (improvement). Measuring gains from offsetting using projected values, adds significant uncertainty to offsetting (Gordon *et al.* 2015; Maron *et al.* 2015a; Dorrough *et al.* 2019). If these projections are not plausible, biodiversity offsetting is unlikely to achieve its No Net Loss objective (Maron *et al.* 2018). In particular, overestimating decline without an offset, and/or improvement with an offset, will overestimate the offset gain and allow a larger impact to be exchanged for the same offset, resulting in a net loss of biodiversity and further exacerbating existing biodiversity decline (Salzman and Ruhl 2010; Gordon *et al.* 2015; Maron *et al.* 2015a).

The role of prior management and security gains under the Victorian gain scoring methodology is problematic. Prior management gain rewards landowners on freehold land for maintaining native vegetation at an offset site prior to the offset occurring (Table 1). While maintaining the native vegetation condition is arguably good for biodiversity, any activities undertaken prior to an offset to avert the loss of native vegetation are not providing any gains in native vegetation that are attributable to the offset itself. The incentive behind this gain may be to discourage landowners from intentionally degrading or clearing native vegetation prior to an offset in order to inflate the potential improvement gains. However, this outcome can also be achieved through setting minimum native vegetation condition and habitat requirements for offsets. Victoria's gain scoring manual outlines some minimum vegetation condition requirements for offsets. These include:

1. Any patch of native vegetation must have a minimum 'site condition score'[6] of 30 out of 75; and
2. Any treeless EVCs, such as grassland and wetland EVCs, must have a minimum 'lack of weeds score'[7] of 7 out of 15 (DELWP 2017d).

The prior management gain appears to be a double up of these existing mechanisms, and, as it does not relate to gains attributable to an offset, has the potential to artificially inflate the gains in native vegetation from offsetting.

The security gain is awarded for increasing the administrative protection on the land title in-perpetuity through an on-title security agreement (on freehold) that provides permanent protection status under legislation, such as a Section 69 (*Conservation, Forests and Lands Act* 1987) Agreement, Conservation Covenant (*Victorian Conservation Trust Act* 1972) or a Section 173 (*Planning and Environment Act* 1987) Agreement, through transferring freehold to the Crown or through reclassifying Crown land to *Crown land – Conservation as primary purpose*. Increasing the administrative protection on the land title permanently restricts allowable land uses at an offset site to conservation activities in perpetuity. Therefore, in addition to the maintenance gain, the security gain also accounts for averted loss in native vegetation from foregoing existing land use entitlements. Accordingly, the security gain can be interpreted as a double up of the maintenance gain and could be addressed through minimum offset site security requirements rather than awarding further gain for averted loss. In addition to prior management gain, security gain has the potential to artificially inflate the gains in native vegetation from offsetting.

**Like-for-like Requirements**

Although biodiversity is never truly identical in different locations, like-for-like offsets provide a connection between the impact and the offset by matching certain characteristics of the biota being impacted with that of the offset, such as location, type and condition (Bull *et al.*

2016). Only minimal like-for-like requirements are necessary for a general offset (measured in General HUs) under Victorian offsetting policy. A general offset:

1. must have an SBV score of at least 80% of the native vegetation to be lost; and
2. be located within the same Catchment Management Authority (CMA) or Local Government Area (LGA) as the impact site (DELWP 2017a).

Under a general offset, the offset site does not need to comprise the same vegetation or habitat type as the impact site. This connection between the vegetation community and habitat type impacted and that of the offset is therefore lost under a general offset. Under a species offset (measured in Species HUs) however, the offset must comprise mapped or assessed habitat for the same threatened species as the species offset requirement, though it may be located anywhere in Victoria (DELWP 2017a). General and species offsets must also provide at least the same number of large trees proposed to be impacted, including large trees in patches or as scattered trees (Box 1).

In the next section we present an impact-offset exchange for a general offset that was permitted under Victorian offsetting policy to illustrate how equivalence between losses and gains in General HUs is determined, and to evaluate the gains in native vegetation that were predicted to be generated from the offset.

**Impact-offset exchange: North Central Catchment Management Authority (CMA)**

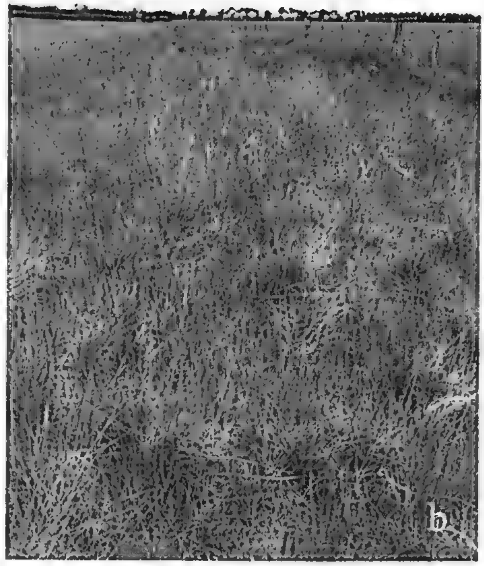
In 2018, a permit holder[8] purchased a general offset from a credit owner[9] in the North Central CMA to compensate for a permitted impact to native vegetation also in the North Central CMA. The offset was purchased prior to the development works being undertaken and met the equivalence requirements under Victoria's 2017 Guidelines. Table 2 summarises the impact-offset exchange and how equivalence between the loss and gain in native vegetation was achieved in General HUs of loss and gain (0.309 General HUs).

The impact covered a long, lineal area that traversed three different LGAs and involved the removal of 0.633 ha of native vegetation, representing six different EVCs of three Victorian bioregions (Table 2). The condition (habitat score) of native vegetation recorded in the impact site varied significantly (11–61/100) from areas of Plains Grassy Woodland (EVC 55) comprising only a low cover of native grasses (Fig. 4b) to more intact areas of Box Ironbark Forest (EVC 60) comprising more diversity in native vegetation life-forms and species (Fig. 4a). The offset

**Table 2.** An Impact-Offset Exchange, North Central Catchment Management Authority 2018

| Attribute | Impact (Loss) | Offset (Gain) |
|---|---|---|
| Catchment Management Authority | North Central | North Central |
| Local Government Area | Central Goldfields, Pyrenees, Hepburn | Northern Grampians |
| Native Vegetation Type | Patch | Patch |
| Area (hectares) | 0.633 | 1.283 |
| Bioregion(s) | Victorian Volcanic Plain, Central Victorian Uplands, Goldfields | Goldfields |
| Ecological Vegetation Classes | Plains Grassy Woodland; Hills Herb-rich Woodland; Creekline Grassy Woodland; Grassy Woodland (Granitic); Box Ironbark Forest; Alluvial Terraces Herb-rich Woodland | Heathy Dry Forest |
| Habitat Score (Condition) | 11-61/100 (0.11-0.61/ha) | 75/100 (0.75/ha) |
| Gain Score | | 31.7 (0.317/ha) |
| Habitat Hectares | (of Loss) 0.252 | (of Gain) 0.41 |
| Strategic Biodiversity Value (SBV) Score | 0.500-0.760 (minimum SBV = 0.515) | 0.517 |
| General Habitat Units (GHUs) | (of Loss) 0.309 | (of Gain) 0.309 |
| Price per GHU (exc GST) | | $80,000.00 |
| Total Offset Price (exc GST) | | $24,720.00 |

Box Ironbark Forest vegetation recorded at the impact site. Photo Ecology and Heritage Partners Pty Ltd, 16 October 2018.



Plains Grassy Woodland vegetation recorded at the impact site. Photo Ecology and Heritage Partners Pty Ltd, 15 October 2018.

Heathy Dry Forest vegetation recorded in habitat zone 1J at the offset site, 2 August 2020.

**Fig. 4.** Photos of the impact and offset sites.

was a portion (1.283 ha) of one habitat zone[10] (known as 1J) within a larger offset site on private land that supported 34.12 ha of native vegetation divided into 12 habitat zones. Habitat zone 1J supports high quality Heathy Dry Forest (EVC 20) vegetation of the Goldfields bioregion (Fig. 4c). This EVC was not representative of the native vegetation impacted in this loss-gain exchange. While the offset in this impact-offset exchange comprises only areas of remnant native vegetation, other offsets under Victorian offsetting policy may include areas of revegetation with indigenous flora species or native scattered trees (DELWP 2017d).

Prior to the offset registration, the offset site was grazed by sheep, and had a significant rabbit population with multiple warrens (pers comm with Landowner, 9 September 2019). The offset was registered on the land title under a Section 69 (*Conservation, Forests and Lands Act 1987*) Agreement in July 2009, which permanently restricts land use to conservation purposes in accordance with the agreement and 10-year offset management plan. Management activities undertaken over the 10-year management period involved the installation and repair of boundary fencing, livestock exclusion, rabbit and fox control, weed control, site monitoring and annual reporting to the Victorian Government (Agreement made under Section 69 of the *Conservation Forests and Lands Act 1987*, 9 July 2009).

The foregone land-use entitlements, on-title security agreement, native vegetation condition (habitat score) and proposed management activities determined the gain points that would be generated from this offset over the 10-year management period in accordance with the former 2006 Victorian gain scoring manual (DSE 2006). The gain points were awarded under each type of gain (maintenance, improvement, prior management and security gains) made up the total gain score of 31.7, or 0.317 per hectare. Both the prior management and security gains (7.5 each) are 10% of the offset habitat score of 75 out of 100, and the maintenance (6.3) and improvement (10.4) gains are the aggregate of points awarded relevant to each habitat attribute, the offset security arrangement and agreed management activities over the 10-year offset management period. Under the updated 2017 gain scoring manual, the same offset would have generated a slightly higher maintenance gain (6.8) and smaller improvement gain (6.4) (DELWP 2017d, 2020d). Table 3 illustrates the gain score per hectare (0.317) multiplied by the total area of habitat zone 1J determined the total gain in habitat hectares (1.81), which, multiplied by the General Landscape Factor, determined the total gain in General HUs (1.373) available from habitat zone 1J.

**Evaluating gains from offsetting**

To achieve Victoria's No Net Loss policy objective, gains from offsetting must be based on plausible projections of future change with and without the offset (Maron *et al.* 2018). If the gains in native vegetation are not plausible, a true equivalence between the impact and the offset may not be achieved.

The maintenance gain is awarded for averting loss in the native vegetation condition over the offset management period (Table 1). At 6.3 gain points, the total maintenance gain awarded to habitat zone 1J assumes that the native vegetation would have declined by 6.3 habitat points or 8.4% in 10 years (an average of 0.63 habitat points or 0.84% per annum) without the offset (Table 3). The prior management and security gains are also awarded for averting loss to native vegetation through offsetting. However, the prior management gain is for averting loss prior to the offset implementation (on freehold land only), and the security gain is for averting loss during the 10-year offset management period through permanent administrative protection which would forego existing land use entitlements and increase the site conservation status. The combined assumption of the prior management, security and maintenance gains is that without the offset, the native vegetation in habitat zone 1J would have declined by 21.3 habitat points or 28.4% in 10 years (an average of 2.13 habitat points or 2.84% per annum).

As discussed earlier, the prior management and security gains have the potential to artificially inflate the gains in native vegetation from offsetting, as they are a double-up of existing mechanisms, including minimum offset standards and the maintenance gain. Maron *et al.* (2015a) found that Victorian offsetting policy assumed one of the largest

**Table 3.** Offset Habitat Zone 1J, Offset Gain Calculator

| | | | | | |
|---|---|---|---|---|---|
| **Habitat Zone** | | 1J | | | |
| **Bioregion** | | Goldfields | | | |
| **EVC name** | | Heathy Dry Forest | | | |
| | | Max | Current condition | Maintenance gain | Improvement gain |
| **Scores** | **Large Trees** | 10 | 2 | | |
| | **Tree Canopy Cover** | 5 | 2 | 0.1 | 0.4 |
| | **Understorey** | 25 | 25 | 2.5 | 0 |
| | **Lack of Weeds** | 15 | 15 | | 4 |
| | **Recruitment** | 10 | 10 | 1 | 4 |
| | **Organic Litter** | 5 | 3 | 0.3 | 2 |
| | **Logs** | 5 | 2 | 2.4 | 0 |
| | **Site Condition** | 75 | 59 | | |
| | **Landscape Context** | 25 | 16 | | |
| | **Habitat Score** | 100 | 75 | | |
| **Subtotal of gains** | | | | 6.3 | 10.4 |
| **Prior Management Gain** | | | | | 7.5 |
| **Security Gain** | | | | | 7.5 |
| **Gain Score** | | | | | 31.7 |
| **Gain Score per hectare** | | | | | 0.317 |
| **Size of habitat zone (ha)** | | | | | 5.7 |
| **TOTAL GAIN (Hha)** | | | | | 1.81 |
| **Strategic Biodiversity Value Score** | | | | | 0.517 |
| **General Landscape Factor** | | | | | 0.7585 |
| **TOTAL GAIN (GHUs)** | | | | | 1.373 |

declines in biodiversity compared to other national policies, at 20–42% loss over a 10-year offset management period, or 2-4.2 % per annum. The study noted that this assumed decline was significantly higher than recent rates of woody native vegetation extent loss in Victoria (0.43% per annum). The assumed decline in native vegetation in habitat zone 1J without the offset under the averted loss gains (2.84% per annum under prior management, security and maintenance gains) is also more than six times this rate. The assumed decline under maintenance gain alone (0.84% per annum) is still almost double this rate. However, as these averted loss gains (prior management, security and maintenance gains) are proportionate to the habitat (condition) score, they may reflect the assumed decline in native vegetation condition without the offset rather than a decline in native vegetation extent, or a combination of both. The Victorian gain scoring manual is not explicit about whether gains from averted loss reflect a loss in native vegetation condition and/or extent.

Using Victorian Government data on estimated decline in native vegetation on private land in Victoria (DSE 2008; CES 2018), it is possible to estimate the annual decline rate in native vegetation condition. Over two time periods, 1994–2004 and 2008–2014, the estimated annual decline in native vegetation condition was 0.5 and 0.52 habitat points respectively (O'Brien 2020). The assumed annual decline in native vegetation condition under the maintenance gain in habitat zone 1J (0.63) is approximately 20% higher than the Victorian Government estimates of decline. The combined assumption of averted loss under the maintenance, security and prior management gains (2.13) is more than four times (400%) higher than the estimated decline in native vegetation condition on private land.

These estimates of decline in native vegetation extent and/or condition in Victoria reveal that for the impact–offset exchange presented here, the projected gains from averted loss from the offset are likely to be overestimated. It also reveals that the prior management and security gains are largely responsible for the scale of this overestimation. Overestimating gains from averted loss is a significant threat to biodiversity from offsetting in Victoria, as it will permit a larger impact in exchange for the same offset. This will result in a net loss of native vegetation in Victoria and further exacerbate biodiversity decline (Salzman and Ruhl 2010; Gordon *et al.* 2015; Maron *et al.* 2015a).

The improvement gain awarded to the offset habitat zone 1J (Table 3) implies that the native vegetation habitat (condition) score will increase by 10.4 habitat points, or by 13.87%, over the 10-year offset management period. As an accredited assessor, one of us (AO) undertook a vegetation quality (habitat hectare) assessment of the native

vegetation in habitat zone 1J on 2 August 2020. The vegetation scored 77 out of 100, an improvement of 2 habitat points or 2.67%, in approximately 11 years. While this assessment may undermine the projected improvement gain for habitat zone 1J, a habitat hectare assessment is not considered a suitable methodology to assess gain by the Victorian Government (pers comm. Angela Robb, DELWP, 20 July 2020). This may be due to the inconsistency between the values used in the habitat hectare methodology compared to the Victorian gain scoring manual.

For example, the assessed habitat attribute score for Tree Canopy Cover in habitat zone 1J is 2. The gain points awarded for the improvement of Tree Canopy Cover from the offset is 0.4 and implies that the habitat attribute score for Tree Canopy Cover would increase from 2 to 2.4 over the 10-year offset management period (Table 3). However, 2.4 is not an available score for Tree Canopy Cover in the vegetation quality (habitat hectare) assessment methodology (DSE 2004). Therefore, the achievement of this value cannot be validated using this methodology. Without a suitable methodology to assess the gain in native vegetation from offsetting, it is currently impossible to verify if any impact-offset exchange achieves No Net Loss. This is a major impediment to achieving Victoria's No Net Loss policy objective.

**Discussion**

Victorian offsetting policy seeks to achieve 'no net loss in biodiversity as a result of the removal, destruction or lopping of native vegetation' (DELWP 2020a). Through examining one impact-offset exchange permitted in the North Central CMA, it is evident that the achievement of No Net Loss is questionable under the current policy framework. While equivalence between the impact and the offset in General HUs was achieved, the gains for averted loss in native vegetation from the offset are likely to be significantly overestimated when compared to available data on native vegetation decline. Exaggerating the gains generated from offsetting undermines a No Net Loss policy objective by permitting a larger impact to native vegetation for the same offset.

The prior management and security gains predominantly contribute to the overestimation of gains in this impact-offset exchange. And, as these gains can be addressed through minimum requirements for offset site security and native vegetation quality, their removal from the Victorian gain scoring methodology may be warranted subject to further review. If habitat zone 1J was not awarded security and prior management gains, the same permitted impact would have required roughly twice the General HUs that were purchased to achieve the same equivalence.

In the absence of a suitable methodology to assess the improved native vegetation condition from offsetting in Victoria, it is not possible to evaluate the plausibility of the improvement gain awarded to the offset presented here. Aligning the gain scoring methodology with vegetation quality (habitat hectares) assessment methodology should be considered to allow for a meaningful evaluation of improvement gains from offsetting. In the interim, a more precautionary approach to awarding gains should be taken to avoid overestimating gains and misrepresenting a No Net Loss outcome.

Greater transparency regarding the underlying assumptions of gains in Victorian offsetting policy will also assist in their evaluation, in particular the source of information or data to support these assumptions, and whether the assumptions for averted loss are reflective of the projected decline in native vegetation condition or extent, or a combination of both. Transparency around the determination of gains from offsetting is essential to demonstrate No Net Loss from an impact-offset exchange. It also allows for continual review, evaluation and improvement of policy outcomes.

**Conclusion**

Under Victorian biodiversity offsetting policy, offsets are required to compensate for permitted impacts to native vegetation and habitat for rare and threatened species with an objective of No Net Loss. Here we have presented details of one impact-offset exchange in General Habitat Units (HUs) to illustrate how equivalence between the General HUs of loss and gain is determined, and whether the gains from this offset are plausible.

Based on available data on estimated decline of native vegetation in Victoria, the gains

awarded to the offset for averted loss (prior management, security and maintenance gains) to native vegetation are likely to be significantly overestimated. In the absence of a suitable offset monitoring methodology, it is not possible to evaluate the improvement gain from the offset. While equivalence between the impact and offsets in this exchange was achieved in General HUs, the exchange is unlikely to have achieved No Net Loss in biodiversity given the projected gains from the offset are either implausible or cannot be validated.

We argue a review of the Victorian gain scoring methodology is urgently needed which should investigate the implications of the prior management and security gains in achieving No Net Loss, and provide transparent data to support the assumptions of averted loss from offsetting. The development of an effective offset assessment framework is essential to validate gains from offsetting and support continual policy improvements.

## Notes

1. The standard unit for classifying vegetation types in Victoria.
2. The average characteristics of mature stands of native vegetation of the same EVC, in the same bioregion, in a *natural* or *undisturbed* condition (DELWP 2020c).
3. A native canopy tree with a Diameter at Breast Height (DBH) greater than or equal to the large tree benchmark for the relevant bioregional EVC.
4. The standardised vegetation assessment methodology used in Victoria to measure native vegetation condition using the habitat hectare assessment method (DSE 2004).
5. A landscape-scale approach to classifying the environment into biogeographical regions using a range of attributes such as climate, geomorphology, geology, soils and vegetation.
6. The site condition score is determined in accordance with the Victorian Government's *Vegetation Quality Assessment Manual—Guidelines for applying the habitat hectares scoring method Version 1.3* (DSE 2004)
7. The lack of weeds score is determined in accordance with the Victorian Government's *Vegetation Quality Assessment Manual—Guidelines for applying the habitat hectares scoring method Version 1.3* (DSE 2004)
8. The individual or legal entity with a permit from the relevant planning authority allowing them to undertake development works in accordance with the *Planning and Environment Act 1987*.
9. The individual(s) or legal entity that owns native vegetation offsets registered on the Victorian Native Vegetation Credit Register (NVCR).
10. A contiguous area of native vegetation that represents that same EVC and vegetation condition (habitat score).

## References


Bull JW, Suttle KB, Gordon A, Singh NJ and Milner-Gulland EJ (2013) Biodiversity offsets in theory and practice. *Oryx* **47**, 369–380.

Bull JW, Gordon A, Watson JEM and Maron M (2016) Seeking convergence on the key concepts in 'no net loss' policy. *Journal of Applied Ecology* **53**, 1686–1693.

CBD (Convention on Biological Diversity) (2011) COP Decision X/2: Strategic plan for biodiversity 2011–2020. Available from: <https://www.cbd.int/decision/cop/?id=12268> (accessed July 2019).

CES (2018) Victorian State of the Environment 2018. Commissioner for Environmental Sustainability Victoria. (Melbourne).

DELWP (2017a) Guidelines for the removal, destruction or lopping of native vegetation. Victorian Department of Environment, Land, Water and Planning, East Melbourne.

DELWP (2017b) Exemptions from requiring a planning permit to remove, destroy or lop native vegetation. Victorian Department of Environment, Land, Water and Planning, East Melbourne

DELWP (2017c) Biodiversity information explanatory document: Measuring value when removing or offsetting native vegetation. Victorian Department of Environment, Land, Water and Planning, East Melbourne.

DELWP (2017d) Native vegetation gain scoring manual Version 2. Victorian Department of Environment, Land, Water and Planning, East Melbourne.

DELWP (2020a) Victorian Planning Provisions. Available from: <http://planning-schemes.delwp.vic.gov.au/schemes> (accessed 7 March 2020). (Victorian Department of Environment, Land, Water and Planning, East Melbourne).

DELWP (2020b) Naturekit. Available from: <http://maps.biodiversity.vic.gov.au/viewer/?viewer=NatureKit> (accessed 4 April 2020). (Victorian Department of Environment, Land, Water and Planning: East Melbourne).

DELWP (2020c) Bioregions and EVC Benchmarks. Available from: <https://www.environment.vic.gov.au/biodiversity/bioregions-and-evc-benchmarks> (accessed 7 March 2020). (Victorian Department of Environment, Land, Water and Planning: East Melbourne).

DELWP (2020d) Native vegetation gain calculator (excel). Available from: <https://www.environment.vic.gov.au/native-vegetation/native-vegetation> (accessed 10 August 2020). (Victorian Department of Environment, Land, Water and Planning: East Melbourne).

DEPI (2014) Advisory list of rare or threatened plants in Victoria. (Department of Environment and Primary Industries: East Melbourne).

Dorrough J, Sinclair SJ and Oliver I (2019) Expert predictions of changes in vegetation condition reveal perceived risks in biodiversity offsetting. *PLoS ONE* **14** (5).

DSE (2004) Vegetation Quality Assessment Manual: Guidelines for applying the habitat hectares scoring method Version 1.3. (Department of Sustainability and Environment: East Melbourne).

DSE (2006) Native Vegetation: Vegetation Gain Approach—technical basis for calculating gains through improved native vegetation management and revegetation. (Department of Sustainability and Environment: East Melbourne).

DSE (2008) Native Vegetation Net Gain accounting first approximation report. (Department of Sustainability and Environment: East Melbourne).

DSE (2013) Advisory List of Threatened Vertebrate Fauna in Victoria. (Department of Sustainability and Environment: East Melbourne).

Gibbons P, Evans MC, Maron M, Gordon A, Le Roux D, von Hase A, Lindenmayer DB and Possingham HP (2015) A Loss-Gain Calculator for Biodiversity Offsets and the Circumstances in Which No Net Loss Is Feasible. *Conservation Letters* **9**, 252–259.

Gordon A, Bull JW, Wilcox C and Maron M (2015) Perverse incentives risk undermining biodiversity offset policies. *Journal of Applied Ecology* **52**, 532–537.

IUCN (2014) Biodiversity Offsets Technical Study Paper: A report by the International Union for Conservation of Nature (IUCN) Biodiversity Offsets Technical Study Group. IUCN, Gland, Switzerland.

Maron M (2015) Stop misuse of biodiversity offsets. *Nature* **523**, 401–403.

Maron M, Bull JW, Evans MC and Gordon A (2015a) Locking in loss: Baselines of decline in Australian biodiversity offset policies. *Biological Conservation* **192**, 504–512.

Maron M, Gordon A, Mackey B, Possingham H and Watson J (2015b) Interactions Between Biodiversity Offsets and Protected Area Commitments: Avoiding Perverse Outcomes. *Conservation Letters*, 1–6.

Maron M, Brownlie S, Bull JW, Evans MC, von Hase A, Quétier F, Watson J and Ascelin A (2018) The many meanings of no net loss in environmental policy. *Nature Sustainability* **1**, 19–27.

Maseyk FJF, Barea LP, Stephens RTT, Possingham HP, Dutson G and Maron M (2016) A disaggregated biodiversity offset accounting model to improve estimation of ecological equivalency and no net loss. *Biological Conservation* **204**, 322–332.

O'Brien A (2020) Critical review of assumptions of gains in biodiversity under Victorian offsetting policy. (Unpublished Masters thesis, RMIT University, Melbourne). Available from *OSF Preprints*. <https://doi.org/10.31219/osf.io/nv4za> (accessed 10 August 2020).

OECD (2016) Biodiversity Offsets: Effective Design and Implementation. OECD Publishing, Paris.

Parkes D, Newell G and Cheal D (2003) Assessing the quality of native vegetation: the 'habitat hectares' approach. *Ecological Management & Restoration* **4**, S29–S38. SEWPaC (2012) Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy. Australian Government Department of Sustainability, Environment, Water, Population and Community, Canberra, ACT.

Peterson I, Maron M, Moillanen A, Bekessy S and Gordon A (2018) A quantitative framework for evaluating the impact of biodiversity policies. *Biological Conservation* **224**, 162–169.

Quétier F, Regnery B and Levrel H (2014) No net loss of biodiversity or paper offsets? A critical review of the French no net loss policy. *Environmental Science & Policy* **38**, 120–131.

Salzman J and Ruhl JB (2010) Gaming the past: The theory and practice of historic baselines in the administrative state. *Vanderbilt Law Review* **64**, 1–57.

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## One hundred and three years ago

### Aboriginal plant names: their etymology

by R. A. Keble

*Kan berr*, Prickly Bush Pea, *Pultenæa juniperina*, Labill, comes from kourn, the neck, and berr, to encircle. Some portion of the Prickly Bush Pea was used as a necklace—possibly the seeds or seed-pods. The association of the two syllables in words that refer to ornamentation occurs in kourn burt or kourn but, a necklace made by threading pieces of reed ; kan berr bay, to deck, dress.

From *The Victorian Naturalist* XXXIV, p. 107, September 6, 1917

# Margaret Corrick

## 11 October 1922 — 12 August 2020

Margaret Georgina Corrick, a long-term Member and former President of the Field Naturalists Club of Victoria (FNCV) passed away on 12 August 2020; she was 97.

Margaret was born in Hobart into a nature-loving family. Along with her parents and two sisters she was a member of the Tasmanian Field Naturalists Club. All her schooldays were spent at The Friends' School where she made lifelong friends. She took a job as a bank clerk until her marriage in 1947 to Bill whom she met at the bank. Bank postings took the growing family to Launceston and Leeton, before Casterton in western Victoria in 1962. Two years later they moved to Hamilton. In both the latter towns the family became active members of the local Field Naturalists Clubs. From 1965 to 1968 Margaret was Secretary of the Hamilton club.

Margaret's enthusiasm for native plants was inspired by the flora of the Grampians. Her interest in the local natural environments was fuelled too by the campaign for conservation of the nearby Little Desert and the Lower Glenelg area. During this period, she made regular day excursions into the bush, and longer camping trips, with her four children in tow. On one such trip, among all this diverse flora, family folklore has her saying —'I'm going to study Botany'. The local flora was almost completely unknown to her, and there were few books available. But there were a few knowledgeable naturalists prepared to assist her, including prominent FNCV members Arthur Swaby and Cliff Beauglehole. While at Hamilton, beginning in 1969, she embarked on a project with the local Field Naturalists Club to compile plant lists of the flora of Victoria Range.

In the mid-1970s, now living in Melbourne, Margaret emerged as Secretary of the Botany Group, and the Club's Assistant Secretary from 1973–1975. She served as Vice-President in the period 1975–1976, and finally as President in 1976–1978. In the Club's first 100 years of operation, Margaret was one of only three women who held this position. At the

time, although there were many female members, few of them were prepared (or, perhaps, afforded the opportunity) to serve on the Club's Council, and those who did were in assistant positions. During all of her time as President, Margaret operated without a Secretary, and for part of that time she was also on the Editorial Committee of *The Victorian Naturalist*. In addition, she was Secretary to the General Committee of the Australian Natural History Medallion from 1973–1980, and was for many years the FNCV representative on that committee.

Following a quarter century of home duties, paid employment resumed in 1975 when she was appointed first as a Botanical Assistant and later a Technical Officer at the National Herbarium of Victoria, a position she held until her retirement in 1985. When she joined the Herbarium staff her first task was to incorporate into the collections some thousands of specimens gathered by the former Assistant Government Botanist Jim Willis. She estimated that most of these specimens were collected on FNCV excursions. In 1995 she was appointed an Honorary Associate at the Herbarium which enabled her to pursue her own interests more easily. When she was

presented with her FNCV Honorary Membership certificate in 2005 Margaret said she had gained much from her association with the Club, and that it had contributed to her being employed by the Herbarium. Margaret herself has collected over 10 000 specimens, lodged in State Herbaria across Australia. Most of these were collected in Western Australia during annual spring-time trips with Bill after the birth of their first grandchild in Perth in 1982.

Margaret contributed regularly to *The Victorian Naturalist*, beginning in 1971 with the citation for the award of the Australian Natural History Medallion to Cliff Beauglehole. She had coordinated the process of nominating the winner. In the following 42 years Margaret contributed a further 28 pieces—articles, tributes and book reviews—to the journal. She had become an authority on the genus *Pultenaea* and, of this total, 24 articles focused on the bush-peas of Victoria.

In addition to this output Margaret provided the section on *Pultenaea* in the Flora of Victoria (1996) and, with Bruce Fuhrer, co-authored two books: *Wildflowers of Southern Western Australia* (1996) and *Wildflowers of Victoria* (2000). Margaret also assisted Bruce in the preparation of *A Field Guide to Australian Fungi* (2005).

Margaret Corrick contributed much to the FNCV during her membership of more than half a century. In the words of Sheila Houghton, Margaret 'exemplified the purposes for which the Club had been founded, the self-taught amateur who became an expert in her field.' She also 'gave unstintingly of her time and energy to the Club'. The FNCV Council extends its condolences to Margaret's family.

This tribute is based largely on published articles by Helen Cohn, Valda Dedman and, particularly, Sheila Houghton. I am pleased also to thank Geoff Corrick, who added to and corrected an earlier draft.

Gary Presland
FNCV
PO Box 13
Blackburn, Victoria 3130

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## Frogs and Reptiles of the Murray-Darling Basin: A Guide to Their Identification, Ecology and Conservation

by Michael Swan

Publisher: *CSIRO Publishing, Clayton South, Victoria, 2020. 352 pages, paperback.* ISBN 9781486311323. *RRP $49.99*

Most fauna field guides cover a country, state or bioregion; the new *Frogs and Reptiles of the Murray-Darling Basin* takes a rather novel approach—it covers the herpetofauna of the largest drainage basin in Australia. I must admit, in my first passing thoughts about this concept I underestimated the size of both the Basin and of the list of reptiles and frogs that occur there. The numbers are staggering: well over a million square km across four states and the Australian Capital Territory, containing 244 species of reptiles and 66 frogs!

Given that enormous area, we might expect there to be considerable faunal diversity within the Basin. And indeed there is: the 310 species are spread across four families of frogs, seven families of lizards, four families of snakes, and freshwater turtles. Given the extent of the Basin, there are extremes in almost all physical and climatic properties, as well as habitats ranging from the inland deserts and plains to the highest elevations of the Australian Alps. Consequently, herpetofauna is diverse: alpine species such as the Corroboree Frogs

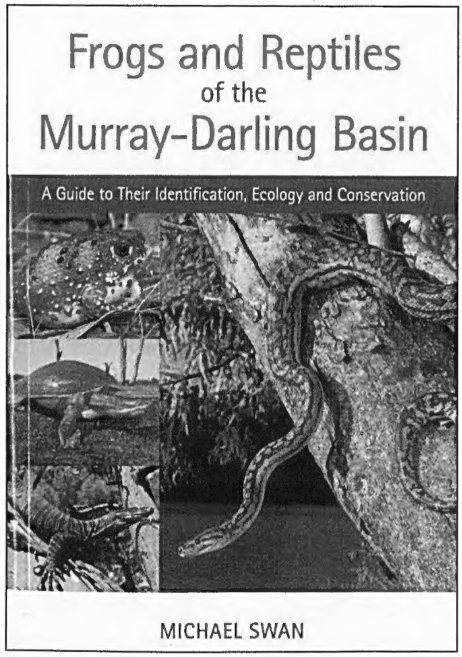
*Pseudophryne corroboree* and *P. pengilleyi* and Alpine She-oak Skink *Cyclodomorphus praealtus*; wet forest dwellers such as the Southern Angle-headed Dragon *Lophosaurus spinipes*; plains species such as the Inland Taipan *Oxyuranus microlepidotus*; and desert species such as the Central Netted Dragon *Ctenophorus nuchalis* are covered. In fact, the Basin provides a truly representative sample of Australia's herpetofaunal diversity.

The Murray-Darling Basin comprises no less than 22 major catchments, and the introduction provides impressive detail on the geographic and hydrological parameters of each catchment, as well as the habitat types and typical herpetofauna of each catchment. Compiling this information for so many catchments is no small undertaking!

The illustrations are outstanding. Rachael Hammond take a bow—you have produced the finest technical illustrations that I have seen in any herpetological guide! Photography in modern field guides is usually very good, and this book is no exception. The images exquisitely capture the remarkable beauty and diversity of the reptiles and frogs of the Basin. Swan is an accomplished photographer, and contributed many images. Numerous other herpetologists have contributed outstanding photographs, but special mention needs to be made of Jules Farquhar, whose images stand out in terms of both volume and exceptional composition and quality.

Accurate, informative and useful introductions are given for the major groups (frogs, turtles, lizards and snakes), and then for each family and genus. Importantly, key physical features described in the text are clearly portrayed in labelled illustrations by Hammond. Unless one has a photographic memory, these illustrations of features such as scale and stripe names are very helpful, even for seasoned herpetologists. Similarly, the inclusion of a comprehensive glossary of technical terms is helpful not only when using this book, but also when reading other literature on reptiles and amphibians.

Given the very large number of species covered, the detail in the profile for each species is impressive. Included are: common name, scientific name, size, description, habitat, notes (such as behaviour and traits), identification,




conservation status at both state and national levels, and a list of relevant catchments in which the species occurs. Combined, this information provides a very well-rounded 'picture' of each species. For a tiny minority of species that are the subject of current research, a second edition of this book will benefit from having researchers' input into technical details, but the general quality of information is excellent.

Swan wisely includes information on snakebite first aid, but I would have liked to see this section included in the contents; in a snakebite emergency such information needs to be found quickly. The inclusion of comprehensive species lists cross-referenced by catchment is welcome.

This is a very attractive book that is easy to use for its intended purpose. The photographs (and indeed the drawn illustrations) will delight the reader. I see this book being of interest and value to an audience ranging from herpetologists to field naturalists and even farmers in the massive Murray-Darling Basin.

**Nick Clemann**
Arthur Rylah Institute for Environmental Research
Department of Environment, Land, Water and Planning
PO Box 137
Heidelberg, Victoria 3084

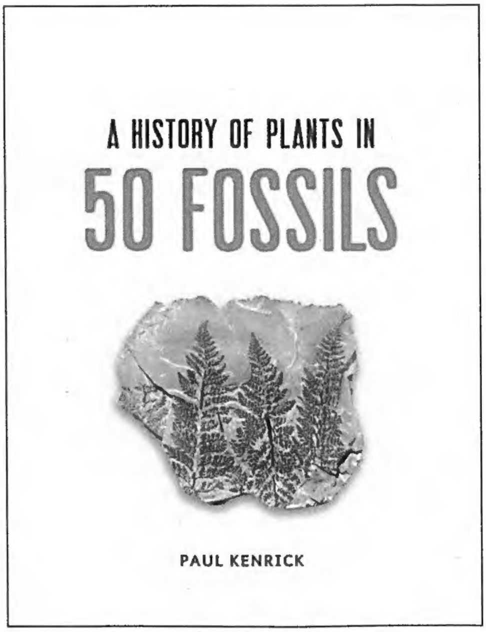
# A History of Plants in 50 Fossils

by Paul Kenrick

Publisher: *CSIRO Publishing, Clayton South, Victoria, 2020. 160 pages, hardback, colour illustrations and photographs. ISBN 9781486313648. RRP $34.99*

This book, first published by the Natural History Museum (London, UK), is now published under an exclusive (Print only) licence in Australia and New Zealand by CSIRO Publishing. Using, almost exclusively, specimens from the Natural History Museum (London), Professor Kenrick illustrates the history of plants from the time they first appeared in the fossil record until the present day.

The fifty vignettes take us on a journey from the appearance of photosynthetic organisms in the marine environment through the first steps onto land, highlighting the key evolutionary innovations that enabled these transitions and saw the development of the complex ecosystems that we see today. It is a story of adaptation and how particular adaptations enabled groups to thrive and dominate terrestrial ecosystems. Woven into these fossil vignettes is the impact of these evolutionary innovations on the planet: the rise of oxygen and ultimately fire, the feedback between life and environment, and ecological relationships between species. The book touches on other interesting aspects of palaeobotany such as how fossil plants have influenced scientific recognition of plate tectonics and continental drift. It also provides insights into how our understanding of present day processes can be used to interpret the past. The vignette on *Ginkgo huttonii* stomata demonstrates how past levels of atmospheric carbon dioxide are determined from fossil material, while the section on *Azolla* highlights some of the unexpected aspects of the fossil record. The Eocene (*circa* 54 million years ago) Arctic Ocean was covered in a layer of fresh water that supported blooms of *Azolla* covering an area the size of Europe. These seasonal blooms were thought to have drawn down significant amounts of carbon dioxide and contributed to the cooling of the Earth, leading to Antarctic glaciation.




This a well-written and produced book that makes accessible the importance of fossils in understanding our natural world, and the role that plant life has played in shaping the planet we live on.

If you are interested in how the environment has shaped plant evolution and, in turn, how the evolution of plant life has shaped ecosystems and planetary processes, this book provides a series of beautifully illustrated examples.

**David Cantrill**
Executive Director Science
Royal Botanic Gardens Victoria
Melbourne, Victoria 3004